U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building Technologies Program

Measuring State Energy Code Compliance

REPORT released March 2010

subject to further development

Prepared by Pacific Northwest National Laboratory
for the U.S. Department of Energy Building Technologies Program
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161
ph: (800) 553-6847
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

PNNL-19281

Measuring State Energy Code Compliance

REPORT released March 2010
subject to further development

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

To help the nation achieve the economic, environmental, and national security-related benefits of increased energy savings, the American Recovery and Reinvestment Act (Recovery Act) referred to specific building energy codes and standards for states to adopt, as well as codes-related activities at the state and local level. These include activities in support of code implementation and enforcement as well as measurement of the compliance rate associated with the codes and standards named in the legislation. Through the present document, the U.S. Department of Energy (DOE) and its Building Energy Codes Program (BECP) provide a detailed set of procedures that may help states as they engage in these activities, most notably those associated with measuring and reporting rates of compliance.

First, the importance of building energy codes is discussed, along with state activities in support of their governors' assurances to the Secretary of Energy in response to the Recovery Act, including specific information on codes and standards "equivalent" to those named in the legislation. This is followed by material that states may consider during strategic planning, including setting protocols for annual measurement, conducting an initial self-assessment of compliance and combining that with education and outreach activities, choosing an approach for evaluating code compliance, and factoring in the funding and personnel available to begin and sustain these functions. In these areas, alternatives, examples, and resources are provided, as well as other helpful information.

The focus of the document, however, is the specific onsite compliance measurement procedures found in Section 5. This section includes information, examples, and mathematical validation with respect to the building populations, generation, makeup, and distribution of samples, as well as procedures for generating metrics for individual buildings and aggregating them into state compliance metrics. This information, as well as the rest of the document, is provided as part of BECP's technical assistance to states. These compliance evaluation procedures are being developed (and refined through the use of pilot studies) to help states save the resources and funding that would be needed in order to develop procedures from scratch. Moreover, the use of these materials ensures comparable evaluations from state to state. There is no requirement for a state to use these materials; rather, they are provided as part of DOE's goal to help states achieve greater energy savings through effective building energy codes. BECP support is also available to help establish state building sample sets, compile and evaluate the results of compliance evaluations, and to provide additional training materials during the process. Section 5 presents the overarching recommendation that states conduct compliance measurement procedures based on the evaluation of a statistically significant sample of approximately 44 buildings (more or less for some populations in some states) in each of the following four building populations:

- residential new construction
- commercial new construction
- residential renovations
- commercial renovations.

This document also provides further information on the appropriate makeup and distribution of these samples, provisions for states with very large buildings or relatively small populations, and the proper use of compliance evaluation checklists. Because these recommendations may be refined through upcoming pilot studies, this document is subject to further revisions, which will be specified in subsequent versions.

Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program (DOE)
DOE	U.S. Department of Energy
EPACT	Federal Energy Policy Act of 1992
HSPF	Heating Seasonal Performance Factor
HVAC	Heating, Ventilating and Air-Conditioning
IBC	International Building Code
ICC	International Code Council
IECC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
ISO	International Organization for Standardization
NFRC	National Fenestration Rating Council
SEP	State Energy Program
SHGC	Solar Heat Gain Coefficient

Contents

Figures

Tables

1.0 Introduction

The current economic, environmental, and energy security challenges facing our nation make the achievement of greater energy savings a major priority. "Energy savings" can be defined from several perspectives: most prominently, these include lessening costs, carbon emissions, and dependence on foreign oil. Since buildings use roughly 40% of our nation's energy, activities related to building energy codes and standards represent a key factor for achieving energy savings and the corresponding benefits to the nation. The American Recovery and Reinvestment Act (Recovery Act) has recognized this priority as parallel with its major economic intentions, and has allocated funding to states as such.

In response to the Recovery Act, State Governors sent letters of assurance regarding energy codes to the Secretary of Energy. A number of states are following up on these letters by beginning to develop plans for measuring compliance with their codes, based on the 2009 International Energy Conservation Code[1] (2009 IECC) for residential buildings and the ANSI/ASHRAE/IESNA[2] Standard 90.1–2007 (90.1-2007) for commercial buildings, or equivalent codes. They are also developing plans to achieve 90% compliance with these target codes within eight years, and for an annual measurement of the rate of compliance. The 2009 IECC and Standard 90.1-2007 are referred to in this document as the "target codes" against which compliance is measured.

Even after the 90% compliance rate is demonstrated, states may want to continue their efforts to monitor code compliance in order to continue achieving the benefits associated with energy savings. Changes in building department staff and processes, as well as changes in builders, designers, and contractors, make periodic evaluations a necessity in order to ensure continued high energy code compliance rates. This is supported through jurisdictional evaluations performed over past years. Such evaluations have demonstrated that changes yield consequences that are not always in a positive direction, and can depend on many variables that require ongoing review to understand and address.

The U.S. Department of Energy (DOE) and its Building Energy Codes Program (BECP) are providing many forms of support to help states enhance activities related to building energy codes. The present document is part of that effort. Herein, BECP provides recommended processes that are being developed to help states measure compliance with their building energy codes; also included are considerations about the codes themselves and suggestions regarding the improvement of building energy code compliance. Specifically, Section 2.0 addresses the equivalency of several alternative codes with the target codes; Section 3.0 discusses annual reporting alternatives; Section 4.0 discusses state strategies for personnel, funding, and oversight with regard to code compliance efforts; Section 5.0 provides a methodology for conducting a formal compliance evaluation; and Section 6.0 introduces the compliance checklists BECP recommends for conducting these evaluations.

[1] The Recovery Act provisions reference the most recent International Energy Conservation Code (IECC) for residential buildings. The 2009 IECC was published in January 2009, shortly before the Act was signed February 14, 2009.

[2] The American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers/Illuminating Engineering Society of North America.

2.0 Code Adoption and Equivalency

Measuring compliance with a code, of course, comes second to having a code in place. While this document is primarily concerned with code compliance, the codes against which compliance is measured must first be considered. This document provides support for compliance measurements with respect to the 2009 International Energy Conservation Code (2009 IECC) for residential buildings (ICC 2009a) and the ANSI/ASHRAE/IESNA Standard 90.1–2007 (90.1-2007) for commercial buildings, or equivalent codes and standards. Many states have either adopted or plan to adopt codes other than these target codes, or they prefer to adopt modified versions of these target codes. The question of "equivalency" is therefore important to such states. This section addresses questions related to the following alternative codes adopted in states:

- The 2009 IECC Chapter 5 for commercial buildings
- The 2009 International Residential Code (IRC) for one- and two-family dwellings
- Low-rise multi-family residential buildings covered under the commercial code
- Codes more recent than the target codes
- Other state-specific codes, whether "home grown" or amended versions of the target codes.

2.1 2009 IECC Chapter 5 for Commercial Buildings

DOE has not made a formal determination as to whether Chapter 5 of the 2009 IECC is equivalent to 90.1-2007 with respect to commercial buildings. However, BECP has performed a comparative analysis of these two codes which indicates that Chapter 5 of the 2009 IECC is mostly equivalent to 90.1-2007 for most systems and in many locations. The comparative analysis lists some system- and location-specific measures where the state may want to conduct additional analysis specifically for its climate zones. For example, the thermal requirements for opaque and non-opaque assemblies are not always identical between the two documents, although the climate zones are identical. In some instances, 90.1-2007 is more stringent, and in others the 2009 IECC Chapter 5 is more stringent. The International Code Council (ICC) also conducted a comparison (ICC 2009b) of the 2009 IECC Chapter 5 and 90.1-2007.

BECP has developed checklists specifically for 90.1-2007 for use in gathering data related to a determination of compliance. Because the structure of and code requirements within the 2009 IECC Chapter 5 and 90.1-2007 are very similar, BECP is recommending that states who have adopted the IECC for commercial buildings use the 90.1-2007 checklists in determining their rate of compliance with Chapter 5 of the IECC. To assist these states, BECP anticipates revising the 90.1-2007 checklists to include the code section numbers for the 2009 IECC Chapter 5 as well as the section numbers for 90.1-2007.

2.2 2009 IRC for Residential Buildings

BECP has performed a comparison of Chapter 11 of the 2009 IRC, which provides energy efficiency requirements for one- and two-family dwellings and townhouses, against the residential requirements of the 2009 IECC. The comparison concludes that states wishing to adopt the IRC while maintaining equivalency with the 2009 IECC should also adopt the six amendments suggested in the BECP comparison. At this time, BECP does not anticipate developing separate compliance checklists for the IRC, and recommends that the checklists developed for the 2009 IECC be used to gather data even if the state has adopted the IRC. The codes are alike enough in structure that the same checklists can be used. BECP does, however, anticipate updating the 2009 IECC checklists to contain references to the applicable code sections of the IRC as well as those of the IECC.

2.3 Low-rise Multifamily Buildings Covered Under the Commercial Code

In some states, such as Indiana and Wisconsin, low-rise multifamily buildings (three stories or less in height above grade) are subject to the commercial code. In these states, evaluations of such buildings can be based on the 2009 IECC Chapter 4, or the state's commercial code can be analyzed for equivalency to the 2009 IECC Chapter 4 in the applicable locations. The latter approach may be difficult, however, since a comparison of requirements is dependent on climate zone (e.g., individual code requirements may be more stringent in one climate zone and less stringent in another).

An initial evaluation by BECP concludes that there are several differences in efficiency requirements between 90.1-2007 (and 2009 IECC Chapter 5) for commercial buildings, when compared to 2009 IECC Chapter 4 for residential buildings. The differences vary by climate zone and by system type (e.g., building envelope, mechanical, and lighting systems). In general, a building that complies with the requirements applicable to commercial buildings instead of the requirements applicable to residential buildings will under-comply for the building envelope in cold climates and over-comply on solar heat gain coefficient (SHGC) requirements in hot climates. Mechanical system requirements should be comparable because the 2009 IECC Chapter 4 for residential buildings refers to the IECC Chapter 5 for commercial buildings for multi-zone heating, ventilating, and air conditioning (HVAC) system requirements. Interior and exterior lighting under commercial codes (either the 2009 IECC Chapter 5 or 90.1-2007) is more stringent than under 2009 IECC Chapter 4 for residential.

Based on these differences, it would be inaccurate to say that a building that complies with one set of requirements automatically complies with the other. There are unique requirements in the 2009 IECC Chapter 4 that do not appear in either 2009 IECC Chapter 5 nor in 90.1-2007. Therefore, where a state's low-rise multifamily buildings are subject to a commercial code, BECP recommends evaluating these buildings against the 2009 IECC Chapter 4 instead of against the commercial code that has been adopted and applied to these buildings.

2.4 Codes More Recent than the Target Codes

States are developing plans for achieving 90% compliance against the target codes within eight years, as well as developing annual compliance measurements. During this 8-year period, it is certain that more recent codes, such as the 2012 IECC and ASHRAE 90.1-2010, will be developed and could possibly be adopted by states. If the format of these new codes is similar to the format of the target codes, the checklists developed for the target codes would continue to be applicable. Under the assumption that the newly adopted codes will be more stringent than the current target codes, the state should have higher compliance against the older, less stringent code. If the format of these newer codes changes substantially, BECP will generate checklists appropriate for evaluation against these newer codes.

2.5 Other State-specific or Amended Codes

Where the state wishes to confirm that their state-specific or amended code is as energy-efficient as the target codes, states can request DOE to evaluate the state code against the target code. BECP has provided similar evaluations in the past by comparing state codes to national codes to determine if the state code meets or exceeds the national codes. Where state-specific codes are modeled after the IECC or 90.1 national codes, the framework used in these previous comparative evaluations can be used to provide similar evaluations in the future.

BECP guidelines and tools can be modified by the state to ensure they work with the state's code requirements. For codes similar in structure to the target codes, this will typically involve minor modifications to the evaluation checklists and the corresponding instructions provided with those checklists. Any state can evaluate code compliance against their specific code requirements using the same measurement guidelines as states that have adopted the target codes.

If a state's code is not deemed equal to or more stringent than the target codes, the state may still see value in evaluating code compliance against the checklists developed for the target codes. In some cases where the code requirements have not changed drastically, a state that has adopted an older version of the IECC or Standard 90.1 may be able to demonstrate that its buildings are 90% compliant with the target codes even though those codes have not been adopted. In these cases, the states should use the checklists developed for the target codes (e.g., the 2009 IECC and/or 90.1-2007).

3.0 Annual Measurement

Training and related support programs can facilitate code compliance and an annual measurement of the rate of compliance. In some states, formal annual onsite evaluations as described in Section 5 may not be feasible or productive because of a lack of manpower, because nothing has changed since a previous onsite audit, or because the state intends to wait until a newer code is adopted. To address this, the current section offers states alternatives for conducting an annual measurement and a roadmap for doing so in concert with other more traditional and ongoing programs. This includes the ability for states to establish effective mechanisms to enhance the level of compliance through various assessment methodologies that are conducted concurrent with traditional energy codes support programs, such as education and training activities.

There is no single methodology for conducting an annual measurement of code compliance. Section 3.1 provides a roadmap for using jurisdictional staff to make an initial assessment of compliance rates, as well as how that effort can be rolled into training and educational activities focused on increasing the compliance rates where necessary. Sections 3.2 and 3.3 provide alternative methods for making initial compliance rate assessments prior to conducting a formal evaluation. Suggested methodologies for conducting the more formal evaluation are provided in Section 5.0.

3.1 Self-Assessment Prior to Adoption

Many states may need to focus early efforts on adoption of the target codes before conducting a formal assessment of compliance against them. Assessment of compliance with current codes can help identify areas needing reinforcement concurrent with adoption of target codes. Training and annual measurements can be implemented by conducting self-assessments using existing and/or newly-hired building department staff to evaluate buildings that are not yet subject to the new, target code(s). In moving toward achieving a 90% compliance threshold, these self-assessment results can identify areas in need of reinforcement through education and training, and can also be used for reporting the yearly compliance measurement.

Consider an analogous example of walkers, joggers, and runners who all share a goal of covering 5 kilometers in 30 minutes. For some individuals this may be a daunting task; for others it is an everyday run. Each participant would undertake appropriate training, reading, diet adjustment, and equipment purchase during the months leading up to the race, based on assessments of their health and conditioning, and their athletic abilities.

Like our analogous runners, a state should be able to focus on and use a combination of self-assessment by local code agencies, identification of areas needing improvement, training and reinforcement to address those areas, and further self-assessment, leading to a final assessment conducted by an accredited third party. Suggested steps for using self-assessments and training on the road to 90% compliance are provided in the following sections and illustrated in Figure 3.1. Variations on these steps are equally viable, such as performing the self-assessments in the field as part of an educational program.

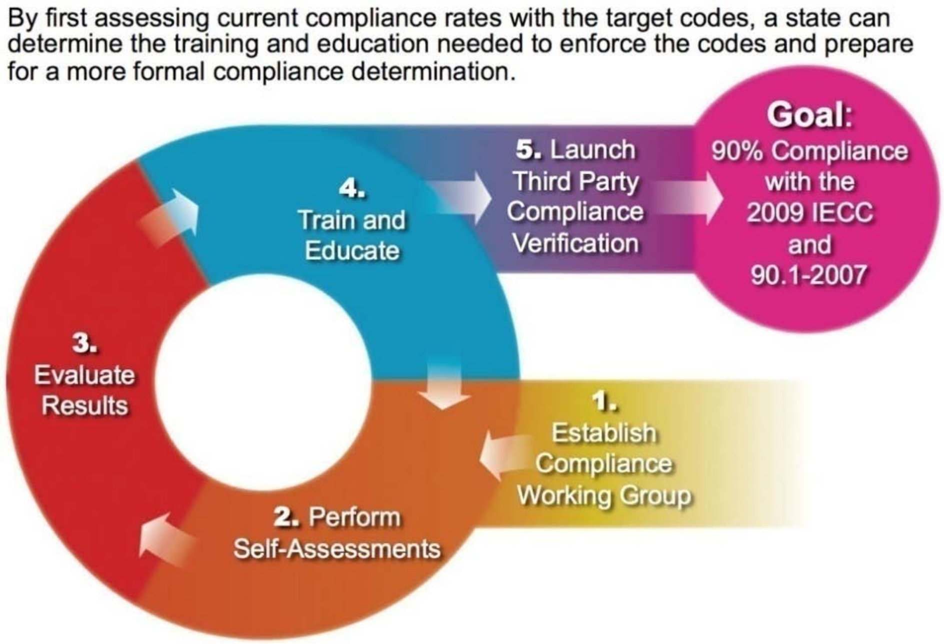

Figure 3.1. Self-assessment and training on the road to compliance

3.1.1 Step 1: Establish Compliance Working Group

An initial step in addressing the code compliance requirements could include establishing a collaborative Compliance Working Group. The state may want to partner with any number of stakeholders, which might include representatives from the state energy office, state code agencies, the governor's energy advisor, state or local code official associations, home builder associations, American Institute of Architects (AIA) chapters, ICC Chapters, contractor associations, Building Owners and Managers Association (BOMA) chapters, and ASHRAE chapters. Also, it will be beneficial for states to bring personnel from third-party evaluators on board during these early stages, both for the education of the evaluators themselves, and to familiarize them with stakeholders in their jurisdictions. Early collaboration among these groups can assist in preparing for a self-assessment program, which may include the following two activities:

- **Review Code Compliance Evaluation Materials**. Review compliance evaluation materials for use by and within the state, such as the procedures and compliance checklists offered by BECP and described in this document. These materials can be used directly to perform a self-assessment of compliance rates with the 2009 IECC and 90.1-2007, or they can be adapted to evaluate compliance rates with codes deemed equivalent.

- **Establish Reporting Mechanisms.** Through a state agency, state code officials association, or other entity, establish a process and mechanism for reporting, aggregating, and analyzing the results of self-assessments.

3.1.2 Step 2: Perform Self-Assessments

While BECP recommends that the final compliance evaluation be performed by third-party evaluators, local code agency staff can be used in assessing the current compliance rate in selected jurisdictions. If the compliance rate does not appear to be acceptable, the results from these self-assessments can be aggregated and used to identify the primary issues/barriers contributing to a reduced compliance rate. Evaluating current construction for compliance would also serve as an excellent training tool for local jurisdictions while providing feedback needed to determine education and training needs. Compliance self-assessments can be easily coupled with scheduled training programs to provide the trainees with actual field experience while completing compliance self-assessments at the same time.

Self-assessments can begin at any time to evaluate current building practices against the target codes, regardless of the currently-adopted code. Beginning the self-assessment independent of any legislated code change process provides greater flexibility in timing and a comprehensive look at the training needed. Using the evaluation materials decided on by the Compliance Working Group, local jurisdictional staff can be asked to compare current practices against the target codes. This effort will introduce staff and builders to the additional information that may be required on plans, to procedures that may need to be adjusted in plan review and inspection, and will illustrate for the design and building community the changes that may be required in construction practices to comply with the new codes.

For states with earlier adopted codes (such as the 2003 or 2006 IECC) and enforcement mechanisms in place, a self-assessment can be used as a tool to update plan reviewers and field inspectors on the nuances of the 2009 IECC and/or 90.1-2007. This can also provide an opportunity to improve compliance rates through use of evaluation materials, such as inspection checklists. States without adopted codes and no enforcement mechanisms will need to provide more comprehensive training on the energy codes, how they are enforced, and the building science behind those codes. Home rule states with mixed jurisdictions may have a variety of situations and training needs throughout their jurisdictions. States may also want to bring in third-party evaluators as a resource for training and/or peer review, or in preparation for using those third-party training entities as eventual evaluators.

Building department inspectors are charged with recording code infractions and ensuring they are rectified prior to completion. If their job is perfectly performed, the resulting buildings will be 100% compliant. In performing self-assessments, the inspectors may need to pursue a slightly different goal. They will want to evaluate buildings based on the results of the first inspection of each code requirement, not on the final compliance (e.g., after the infraction is rectified). For example, if during a residential foundation inspection, a building inspector finds the insulation does not extend to “10 ft. or the basement floor” as required by code, the inspector may ask that the infraction be fixed. Even if the infraction is addressed by the contractor, the compliance self-assessment should report this as an infraction. Otherwise, the overall self-assessment may result in a higher compliance estimate than would be determined by a third-party evaluator. Additionally, in evaluating the self-assessment results, a need for training local builders/contractors on the code’s basement insulation depth requirement might be missed.

3.1.2.1 Examples of Past Self-Assessments

An assessment prior to code adoption is not unprecedented. In the past ten years, several statewide studies have been conducted which compare current construction practices to various codes. The following state and regional studies are given as examples. Additional compliance studies and baseline studies[3] can be found on the BECP website. The first two studies below illustrate evaluations of buildings against not-yet-adopted codes, and the second two studies illustrate evaluations against existing codes.

An Iowa study, *Iowa Residential Energy Code Plan Review and Field Inspection Training*, evaluated 47 single-family homes and 18 multifamily dwelling units to determine how typical single-family homes in the state of Iowa compared to their current residential energy code, the 1992 CABO Model Energy Code (Britt/Makela Group 2003a). The buildings were also evaluated against the 1995 Model Energy Code and the 1998 and 2000 International Energy Conservation Codes (IECC) to identify potential building practice and energy code compliance documentation problem areas. Enforcement varied widely across jurisdictions, with many plans submitted without required documentation. However, field inspection revealed an average compliance rate for single-family homes of 2.84% above the 2000 IECC. The study revealed documentation needs and specific changes to building practices that would improve compliance rates, such as insulating basement walls and floors above crawlspaces.

The *Indiana Commercial Energy Code Baseline Study* (Britt/Makela Group 2005) is particularly relevant for states without current energy codes. It was prepared while the state was considering adopting the 2003 IECC, and evaluated compliance against that code. It included plan review and on-site field inspection of 55 new commercial buildings in key growth areas of Indiana. The review focused on determining if the building plans submitted for permit complied with the energy code, and if the building was built to the plans and the code. Code enforcement personnel, who at the time of the study did not enforce the commercial energy code, were trained to conduct onsite inspections and to collect construction data. Potential energy code compliance problem areas were identified and documented, such as limited information on plans and non-compliant slab insulation techniques. This information provided insights into what changes would be needed and what challenges faced the design, building, and enforcement community in adopting the 2003 IECC.

In the four-state region of Idaho, Montana, Oregon, and Washington, the *Baseline Commercial Construction Practices in the Northwest* (Ecotope 1998) was prepared for the Northwest Energy Efficiency Alliance (NEEA). This baseline study describes the current commercial building practices in the region. The study describes the applicability of, and compliance with, existing standards in the states. Additional NEEA Market Research Reports are available on the NEEA website.

A Nevada residential energy code compliance assessment was conducted on 200 single-family homes in Northern and Southern Nevada (eight building departments total) to determine how typical single-family homes in the state of Nevada compared to current energy codes and also to identify potential energy code compliance problems related to both plan documentation and building practices (Britt/Makela Group 2003b). Relevant results from this study included the Southern Nevada region finding typical construction met codes that were under consideration, while Northern Nevada found their typical crawlspace construction techniques would not comply under the updated code, and new techniques were needed.

[3] Compliance studies are available on BECP's website at www.energycodes.gov/news/arra/compliance_studies.stm; baseline "best practices" studies are available at www.energycodes.gov/news/arra/baseline_studies.stm.

3.1.3 Step 3: Evaluate Results

Using the reporting mechanisms established by the Compliance Working Group, states may compile the self-assessments made and review potential barriers to compliance. The barriers and issues discovered through self-assessments can be used to develop and implement programs and activities to address the reasons for reduced compliance. The self-assessments made over a one-year period can be combined to report an estimate of the annual measurement of compliance. The methodology for determining the overall compliance rate should closely match the methodology to be used for the final third-party evaluation.

3.1.4 Step 4: Train and Educate

This stage includes development and implementation of educational and outreach efforts to address the barriers and issues identified pursuant to the evaluations mentioned above. Actions may include the following:

- Conducting a meeting of the Compliance Working Group to review training classes and materials for adaptation and use in the state, based on the compliance issues and barriers identified

- Coordinating trainers to make educational materials available to jurisdictions and the design and building community

- Using any number of available communication vehicles to make this program known throughout the state and inform the building industry of the findings and suggested remedies needed to address the issues and barriers

- Discussing specific needs with BECP staff, who may be able to provide assistance if existing materials cannot be found to help address educational needs. States are encouraged to use the BECP staff and resources DOE has made available for this purpose.

3.1.5 Step 5: Launch Third-party Compliance Verification

Steps 2-4 above should be repeated until the state is comfortable that they may be achieving a 90% or higher compliance rate. These cyclic steps may be performed over many years, and may start before the adoption of the target codes and may continue after adoption of the target codes. They may also focus on different jurisdictions or different regional areas in the state at different times. Once the state is comfortable with a self-assessment of its compliance rate, it should launch a more formal assessment using a third-party entity to evaluate a statistically valid sample of buildings in the state. Recommended procedures for performing this third-party evaluation are described in Section 5.

3.2 Surveying the Jurisdictions

Survey mechanisms could provide another alternative and less costly means for evaluating compliance during interim years. A survey of questions pertaining to the jurisdiction's energy code plan review, inspection, and administrative processes could provide some indication of the degree to which energy code requirements are enforced, which, in turn, can inform training and educational decisions.

Surveys can be useful either as a means of generating an initial understanding of the many jurisdictions in the state, or as a follow-up action to an onsite evaluation with a focus on measuring change. BECP materials include a short list of suggested survey questions that states can use for either of these approaches.

3.2.1 Surveying as Initial Contact

A survey mechanism can be used as part of an attempt to introduce jurisdictions to Recovery Act objectives and potential upcoming activities. Jurisdictions that indicate that they perform plan reviews and onsite inspections for energy code requirements, and that their staff have received training on the energy codes, may be assumed to have a higher compliance rate than those that respond negatively to these questions. The state may then want to focus initial training and outreach efforts on jurisdictions that are assumed to have lower compliance rates based on the survey responses. A careful tracking of initial survey responses and later onsite evaluations may help inform an understanding of the strength of correlation between processes and compliance rates, and thus create an opportunity to find out which processes contribute most toward improved compliance, resulting in better guidance on ‘best practices’ for local jurisdictions.

3.2.2 Surveying as Follow-up

During formal onsite evaluations, BECP recommends that the evaluators include a short jurisdictional survey as part of their onsite data collection process. The survey would be completed during the initial onsite evaluation in addition to the building evaluations described in subsequent sections. For interim years, this survey could be updated to see if any processes have changed. If nothing has changed, and the applicable energy code hasn’t been updated, it could be assumed that the previous measurement of compliance is still applicable. Likewise, if the jurisdiction’s processes have changed and/or a new code had been adopted, this would indicate that perhaps the jurisdiction should be revisited.

BECP’s survey questions will be provided via an online survey tool that will be made available to states if they wish to annually query jurisdictions about their energy code compliance processes. The tool can be customized by each state, although a core set of questions would aid in providing uniform results.

3.3 Spot Checks

The survey approach described above could be supplemented or replaced with ‘spot checks’ in jurisdictions that received a lower compliance rate compared to others. A ‘spot check’ is an onsite evaluation of a smaller number of buildings than those deemed necessary for meeting the more formal evaluation procedures recommended in Section 5.0 of this document. The spot checks would not be deemed a statistically valid assessment of compliance, but could be used for annual reporting and could provide some valuable information that, in turn, could be used in training and educational efforts.

3.4 Sample Populations

The formal evaluation methodologies described in this document recommend separate sampling for four different building populations:

- residential new construction
- commercial new construction
- residential renovations
- commercial renovations.

States may choose to focus on one of these populations each year rather than attempt an evaluation of all four during a single year. If, at any time, a valid sampling of one of the four populations provides a resulting compliance score of 90% or better, the state may want to focus on other populations that may not achieve 90% compliance.

4.0 Planning for Compliance Evaluation

A recent Building Codes Assistance Project (BCAP) publication, *Residential Building Energy Codes – Enforcement & Compliance Study,* lists 'lack of manpower' as the third largest barrier to enforcing residential building energy codes and 'lack of funding' as the fifth largest barrier (BCAP 2008). The current section discusses the manpower needs, qualifications, certification, accreditation, and funding mechanisms associated with measuring and reporting the rate of compliance with adopted energy codes. Section 4.1 provides examples of various evaluation approaches; Section 4.2 explores evaluator[4] credentials and programs that can assist in training and certifying those evaluators. Section 4.3 addresses issues associated with the manpower needed to conduct evaluations. Section 4.4 addresses funding models to support state measurement and reporting of compliance.

4.1 Evaluation Approaches

A determination of compliance requires the availability of individuals or entities[5] to gather relevant information concerning compliance. There are three basic approaches that can be used to evaluate building plans and construction with respect to code compliance:

- **First Party**. A first-party evaluation would involve self-reporting of data and self-certification of any results associated with compliance (e.g., "I certify that…."). In this case the entities designing and constructing the building make a statement of compliance. While self-certification could be considered by state and local government for a code compliance program, it is not a recommended approach for a formal code compliance evaluation.
- **Second Party.** A second-party evaluation would be performed by the entity responsible for validating compliance, such as state or local government, through their direct oversight of those designing and constructing buildings (e.g., "you comply with …."). This is preferable to the first approach because the state or local government would actually check the plans and building construction, as opposed to accepting a statement of compliance from the subject entity itself.
- **Third Party.** A third-party evaluation would be performed through a third party that acts on behalf of the state or local agency. In this case, the building owner or developer can retain an accredited and recognized third-party entity that acts on behalf of the state or local agency to conduct a review of the design and construction for purposes of ensuring compliance. Alternatively, the agency responsible for compliance could retain the third party. A third party acting on behalf of state or local government is recommended as the most objective approach.

As an example, some states require regular automobile safety inspections. A first-party evaluation would consist of the automobile owner completing a safety inspection themselves and signing and sending in the results. Some method for determining their competence to do so, as well as penalties for

[4] The term 'evaluator' is used throughout this document to refer to individuals that will visit local jurisdictions to gather data from building plans and conduct field inspections of buildings. Evaluators in this context perform similar tasks to energy auditors and building inspectors, but the terms 'auditor' and 'inspector' are associated with slightly different functions and so are not used in this context.

[5] 'Individuals' are considered independent contractors working alone. 'Entities' are considered corporations, associations, etc. where the corporation or association is ultimately responsible for the services provided and uses employees to conduct work on its behalf.

falsifying data and/or compliance statements, would be needed to make this approach worthy of consideration. A second-party evaluation would consist of the state regulatory agency conducting the inspection itself. A third-party evaluation would include having someone other than the vehicle owner perform the evaluation as an authorized agent of the state, such as a service station. In this case the state would develop and implement a program to certify or accredit those entities acting on its behalf.

In developing programs to address energy code compliance, several different evaluation approaches may be considered.

- **Building department.** The state or local building regulatory agency verifies compliance as they do on a regular basis through plan review and inspection. This could be viewed as another form of self-certification in that the building department staff would be gathering data that would be used to assess their own work associated with building plan review and inspection.
- **Public sector third-party agency.** A state agency, commission, or other official arm of state government not having direct responsibility for code compliance verifies compliance. This is done in some states where a state agency is responsible for oversight of local government enforcement of a state building or fire code. The state agency can accredit local government agencies, which would not have a vested interest in the outcome, to enforce the state code. As an example, state compliance programs associated with statewide modular construction regulatory programs could be tasked with evaluating energy code compliance at the local level for residential buildings.
- **Private sector third-party entities.** Anyone who does not have a vested interest in the outcome of a compliance evaluation and is not a public sector agency would be classified as a private sector third-party entity. These can include any number of individuals and entities such as Home Energy Raters (HERS), energy service providers (utilities), architects, engineers, contractors, builders, code officials and others. Included as private sector third parties are energy consultants with experience in this field who have conducted energy code compliance and audit studies. If third-party evaluators are paid by the entity being evaluated, appropriate measures should be in place to ensure their objectivity. For a formal compliance evaluation, the preferred approach would be for evaluators to be under contract with the state or local jurisdictions, rather than being under contract with the entity being evaluated. In all instances these third parties would need to be adjudged as having the qualifications to conduct the required work.

While BECP recommends a third-party evaluation for the formal 90% compliance determination, states may want to expend initial efforts in measuring their current compliance rate via pilot studies and/or self-assessments using local building department staff. Section 3 discusses how these smaller and/or less formal approaches could be used for an annual measurement and to inform training efforts.

In determining who should gather compliance-related information, the states should consider these approaches in relation to the current building regulatory process, licensing, and enforcement conditions in the state. What may work well for one state may not work well for another. It will be important for the state to choose a defensible and objective evaluation approach that fits its capabilities and works within or in concert with its current building regulatory programs and funding mechanisms.

4.2 Certification and Accreditation

A complete program to evaluate compliance should include verification or certification of those individuals or entities performing the evaluations. Such a program should verify their competence in gathering and evaluating information related to compliance. In short, evaluators must be qualified to do the necessary work, and this determination must be made by a qualified source. Since the building design and construction process involves many steps from plan review to final inspection, evaluating these qualifications can become quite complex, as each step requires different knowledge and experience. An expert in performing energy analysis based on building plans is not necessarily qualified to conduct inspections of complex HVAC or lighting control systems.

Certification involves the process of determining if an individual or entity has necessary qualifications to gather the requisite data and perform an evaluation based on those data. Accreditation involves the evaluation and validation of programs or entities that offer certification. Building departments, acting in an accreditation role, can and do allow others such as architects and engineers to conduct plan review and inspection on their behalf or on behalf of building owners, in order to speed up the approval process when those entities have been approved by the building department and can provide assurances that they have no vested interest in the outcome of their efforts.

States will want to validate the objectivity and competence of those who conduct compliance evaluations. Uniformity may be achieved through state recognition of one or more accredited professional certification programs or by having the state develop and implement a program itself to train and evaluate individuals and entities as to their ability to conduct the compliance-related work. Where the state does not directly oversee the work of these individuals, third parties must be used, and the competency of these entities to accredit compliance-related programs becomes a consideration.

Determining competency of individuals and entities involves the following:

- A description of the evaluation tasks to be done and qualifications needed to do those tasks in a competent manner
- Testing that can be used as a basis for determining if a particular individual is competent to perform the tasks
- Ongoing certification to check on the performance of those individuals to determine their continued acceptability to perform the tasks
- Registration with appropriate public or private sector entities to identify who is qualified to perform the tasks
- Considering, in some cases, the availability of accreditation by another entity to validate the competency of those administering tests and issuing certifications.

As reported by the US Bureau of Labor Statistics,[6] many states and local jurisdictions require some type of license or certification for employment as a construction and building inspector. Requirements for licensure or certification may include the following:

- A minimum level of education

[6] For more information, please visit www.bls.gov/oco/ocos004.htm.

- Previous experience
- A state-approved license or certification
- Purchase of liability insurance of a certain amount.

4.2.1 Further Resources for Certification and Accreditation

Some states have developed their own unique licensing programs for inspectors, while others may reference and require certification by national associations in lieu of developing and maintaining their own programs. For instance, some states require home inspectors to obtain a state-issued license or certification. Certification renewal is typically required every few years and annual continuing education is almost always required. States that have such programs may already have a foundation for validating the acceptability of those who would be involved in energy code compliance evaluations. Another basis for validating evaluator competency to address energy code compliance could include existing state licensing regulations and programs for designers and/or contractors. State-specific licensing and certification requirements are provided at http://www.hometraining.com/certif.htm and on the American Society of Home Inspectors website at http://www.ashi.org/customers/state.asp, which lists 32 states having regulations affecting home inspectors.

The most obvious national certifications for this effort come from the organizations responsible for the target codes, the International Code Council (ICC) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

ICC's certification programs are geared towards code officials. ICC's website (http://www.iccsafe.org/) has considerable information about certification programs. ICC certifications include:

- Commercial Energy Inspector
- Commercial Energy Plans Examiner
- Residential Energy Inspector/Plans Examiner.

ASHRAE's website (http://www.ashrae.org/) lists its certification program at http://www.ashrae.org/certification/. Their high performance building design professional certification includes Standard 90.1-2004, but does not yet include 90.1-2007. This is a "design certification" and not an "inspection certification," as ASHRAE is not an inspection or enforcement agency. However, knowledge of Standard 90.1 is certainly helpful and relevant to commercial building energy code compliance. Also available is an online list of ASHRAE Certified Professionals by category - most relevant will be those listed under High-Performance Building Design.

Some ongoing national, state or local building quality assurance and quality control programs employ qualified individuals and/or certify the competency of individuals. Examples include:

- American Home Inspectors Training Institute (www.ahit.com) trains and certifies home inspectors.
- American Institute of Architects (http://www.aia.org/index.htm) requires architects to participate in continuing education as a condition for retaining recognition by the institute.

- Building Performance Institute (www.bpi.org) certifies individuals with regard to competency for energy auditing of homes associated with the DOE Building America Program.
- Construction Specifications Institute (www.csinet.org) offers certification for construction specifiers.
- U.S. Department of Housing and Urban Development (www.hud.gov) offers accreditation of design review and in-plant inspection agencies for manufactured housing.
- Residential Energy Services Network (RESNET) (www.natresnet.org) offers training and certification of home energy raters and offers an online directory of RESNET raters.
- US Green Building Council (http://www.usgbc.org/) offers Leadership in Energy and Environmental Design (LEED) professional accreditation.
- National Certification Program for Construction Code Inspectors (NCPCCI) (www.prometric.com/ncpcci) offers personnel certification for building, mechanical, plumbing, fire and electrical issues.
- National Inspection, Testing and Certification Corporation (NITC) (http://www.nationalitc.com/) offers personnel certification for selected mechanical- and plumbing-related inspections.
- Contacts for State Licensing Boards for architects and engineers are available online, including at http://www.constructionweblinks.com/Industry_Topics/Licensing__Industry_Topics/Finding_Tools__Licensing/finding_tools__licensing.html.

In considering the recognition of any certification program, it is important to consider the basis for acceptance of those who are certified pursuant to the program. Where states decide to implement their own accreditation of personnel certification programs, the following resources may prove useful:

- The International Organization for Standardization (ISO) Standard 17020 entitled "General Criteria for the Operation of Various Types of Bodies Performing Inspection" (http://www.iso.org/iso/catalogue_detail.htm?csnumber=29342)
- ISO/IEC Standard 17024 "General Criteria for Bodies Operating Certification of Persons" (http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?ics1=03&ics2=120&ics3=20&csnumber=52993)
- American National Standards Institute (ANSI) administers two accreditation programs for personnel certification agencies (https://www.ansica.org/wwwversion2/outside/PERgeneral.asp?menuID=2)
- International Accreditation Service (http://www.iasonline.org) accredits building departments with regard to their ability to carry out building regulatory program implementation. They also accredit third-party permitting, plan review, and inspection service providers using IAS acceptance criteria AC 402.

4.3 Manpower

Regardless of the chosen approach to validate compliance, additional manpower resources will be needed to gather data directly from the field, oversee third-party evaluation efforts, and/or evaluate the collected data. Where compliance is below 90%, resources will also be needed to develop and implement programs to address compliance issues. Knowing the reasons for lack of compliance can help state and local agencies more effectively allocate their limited resources to those areas needing the most reinforcement and yielding the biggest payoff in increased rates of compliance.

Even where state and local agencies already conduct plan review and inspection to validate code compliance, many agencies will not have available resources to conduct evaluations, especially since such resources are funded through permitting revenue. When construction activity is down, fewer resources are available. Additionally, code compliance assessment activities may not be covered by permitting funds since they are over and above what is covered by the permitting function.

Several options exist to secure the additional manpower resources needed to enhance energy code compliance, noting that they are affected by available funding, which is discussed further in Section 4.4.

- The Recovery Act is job-creation legislation. Thus, Recovery Act reporting provisions include demonstration of how funding has resulted in new jobs.[7] This is an opportunity to train more individuals on building construction and energy topics through job programs, colleges and universities, and trade schools. Personnel can be hired to augment existing state and local agency staff. Agencies can draw from the unemployed, youth entering the job market, or personnel with backgrounds in construction, utility, consulting, lending or real estate industries.
- Energy code provisions relate to building, mechanical, plumbing, and electrical issues. Personnel currently focused on non-energy-related aspects of the code could be cross-trained to supplement their expertise, enabling them to inspect energy code requirements along with their typical inspections. This leverages Recovery Act funding to support not only enhanced energy code compliance but concurrently to reinforce needed health and life safety considerations.
- Creative opportunities exist to not only support enhancement of local government staff but also state agency staff that can be available to assist local government. For example, some states have a state code agency with staff responsible for assisting local government. Recovery Act funding could be used to bolster the staff in such agencies, providing additional assistance to local government.
- Recovery Act funding can also be used to retain third parties to oversee and/or conduct compliance efforts. This could be implemented in a number of different ways.
  - State or local governments could use a more traditional code enforcement approach and simply retain third parties to augment state and local resources as needed.
  - State or local governments could develop and administer a program to accredit and certify third parties, who in turn could be retained by owners/developers to document and validate code compliance. Such third parties could include consultants, designers, engineers, code officials, utility staff, realtors, and any other individual or entity having the necessary qualifications.
  - State or local governments could rely on self-certification by licensed builders and contractors and use new resources to manage the licensing program, conduct spot inspections and suspend the licenses of those found in non-compliance. While this is not a recommended approach for a formal compliance evaluation (self-certified buildings will need further evaluation to be included in the state sample), it is mentioned here as a potential long-term approach for improving energy code compliance.

[7] Information about funding recipient reporting with regard to jobs can be found at http://www.recovery.gov/FAQ/recipient/Pages/Recipient_Reporting.aspx.

- Although unlikely, states may consider the possibility of recruiting volunteers. With growing interest in reduction of greenhouse gas emissions and in energy conservation, it may be possible to find recruits that would donate time in exchange for training and certification.

4.4 Funding

The cost of developing and administering any program to measure code compliance must be considered. Funding is needed not only for the manpower resources noted above, but for indirect costs such as data management, communication, and program administration. In the short term, funding available under the Recovery Act can jump-start and help support these costs. In the long term, since code compliance enhancement goals will continue to have merit, activities to foster compliance will need to be maintained. For example, while BECP guidelines define sample populations for formal compliance measurements, based on buildings evaluated by third-party entities, there is value in continuous training, self-assessment, and spot checking buildings on a smaller scale each year. Spot checks and self-assessments are suggested as a way to meet the annual reporting requirements and as a method for ensuring continued compliance after the eight-year period. Where existing building regulatory programs will not be able to support such efforts, state and local government will need to develop and implement alternative programs that can be sustained under a solid business model. This section discusses some sources of revenue that the state and local jurisdictions may pursue in continuing compliance evaluations.

- **BECP Support.** The BECP state compliance evaluation procedures and corresponding training materials are provided as part of the program's technical assistance to the states. These procedures were developed so the states and their constituents did not have to spend their own funding and resources to develop 50 different sets of procedures. There is no requirement for a state to use these tools and materials, but they are available to help defer costs that may be incurred in implementing the code compliance improvement activities. BECP support is also available to help establish state building sample sets, compile and evaluate the results of compliance evaluations, and to provide additional marketing and training materials.

- **Recovery Act Funding.** BECP technical assistance has been coupled with $3.1 billion in State Energy Program Recovery Act funding and $3.2 billion in Energy Efficiency and Conservation Block Grant funding. Portions of this funding were permitted to be used by the states for such activities such as code compliance. Every state has received this funding, and the amounts awarded can be found at http://www.energy.gov (on the left-hand bar, see the selection box labeled "In Your State").

- **State Energy Program (SEP) Funding.** Federal SEP formula and special project grants have been available to the states for many years, and are likely to continue to be available. This funding can also be used to support code compliance evaluation work. The SEP exemplifies a source of follow-up funding that can be used to continue efforts that started with Recovery Act funding.

- **Revolving Loan Funds**. Revolving loan funds (RLF) can be used to establish long-term funding mechanisms that can in turn extend the impact of Recovery Act funds. By creating an RLF, states are not subject to expiration of the funds after the current three-year Recovery Act timeframe. The only restriction is that the entire amount allocated to the loan program must be loaned in the initial three-year time period. Repayment can be stretched over additional years. Money recaptured through loan payments must be used for the same purpose unless an amendment is approved by DOE redirecting their use. See the link to *Revolving Loan Funds and the State Energy Program* at http://apps1.eere.energy.gov/state_energy_program/recovery_act.cfm.

- **Training and Certification Costs.** Under the third-party approach for compliance evaluation, there is a cost associated with training and certification of the third-party personnel. Generally, the individual desiring professional certification will be required by the issuing entity to pay a fee for taking the required tests and/or demonstrating competence, possibly followed by renewal and training fees for maintaining the certification. In some cases, that fee would be covered by the individual's employer, such as state or local government paying for a code official or other government employee to receive a professional certification. In others cases, the individual may have to pay the cost and would do so because it opens up additional business and/or advancement opportunities that would not otherwise exist for them. Where third-party entities conduct compliance assessments on behalf of government entities, the demand for buildings-related professions (e.g., architects, engineers, and contractors) could drive these professionals to establish and maintain their certifications and to participate in code compliance initiatives. Recovery Act funding could be used to jumpstart the training and certification of a body of professionals qualified to perform third-party evaluations, with a plan for the certification and training costs to later be absorbed by the individuals receiving such training (similar to the approach used for RESNET raters).[8]

- **Assessment of Fees.** The owner/developer typically pays for all design and specification preparation as well as plan review, approval, construction, commissioning, and inspections; although it can be argued that those costs are passed along to purchasers or tenants of their building and their customers. This funding model assumes that whatever means for increasing energy code compliance initially funded via Recovery Act sources would later be absorbed by owners/developers by increasing the fees associated with building permitting and inspection. An increase in permitting fees for all buildings might provide a source of funding that could pay for spot evaluations to be performed on a small sample of those buildings. In many cases, building permit fees go directly into a general fund, which can be a complicating factor in using such fees to fund Recovery Act tasks specifically, but which could be used to permanently establish a protocol for jurisdictional staff to spot check buildings.

  While higher fees can be assessed for all buildings, another approach would be to offer additional service that may provide a market advantage and associate that service with additional fees. For example, the time to secure plan approval and a permit to construct and then go through the construction and inspection phase to occupancy can be significant. That time costs owners/developers money in that they have investments tied up—the longer it takes to get the building occupied, the longer it is before they can secure a return on their investment. For a larger fee, state and local government may offer an expedited review and approval process. This approach is already used in some localities, where for an additional percentage on the permit fee, government agencies will retain qualified architects and engineers to review the plans on their behalf to expedite review and approval. Key to these expediting efforts is reduced time to occupancy which means

[8] Another consideration is the commissioning of new buildings and ongoing re-commissioning of existing buildings to ensure their continued performance. This process has resulted in the creation of commissioning agents who conduct commissioning activities on behalf of owners and developers. Those conducting data gathering and evaluation of energy code compliance would possess many of the same qualifications that would allow them to also serve as commissioning agents.

more timely availability of revenue for the owner/developer. This approach can be used as a voluntary means of securing additional funding for the jurisdiction, but would have no link to the subset of buildings eventually being evaluated. Recovery Act funding for training and certification efforts may result in a third-party workforce that could be drawn on to provide these services.

The benefits associated with a compliant building include operational savings and enhanced marketability. Another voluntary approach could include providing evaluators with marketing materials that can be passed on to owners/developers who choose to purchase their services to evaluate their buildings. Owners/developers may be more willing to pay the increased costs associated with achieving increased compliance if their building becomes more marketable. Above-code programs, such as RESNET and Energy Star, operate under this model by providing branding that identifies the building as more energy efficient. Recovery Act funding could be used to develop processes, materials, branding, and other marketing tools that assist builders in documenting and marketing their code-compliant or above-code buildings. Software tools that are able to report compliance and above-code compliance percentages or indexes could be used in such efforts.

- **Utility Funding.** Additional funding support may come from energy service providers (utilities). Several approaches have been tried in the past, currently exist, or have been proposed:
  - A non-profit Utility Code Group (UCG) in Washington State, formed with utility collaborative funding, trained over 200 individuals to form a third-party pool of individuals to augment state compliance efforts. The cost of this service was borne by the permit holder, but the UCG provided reimbursement to the permit holder of approximately $300-$375 per project. Although the UCG was disbanded in 1997, the services of these circuit riders were used by approximately 50% of Washington jurisdictions and research indicated that code compliance in buildings inspected by these individuals was very high. See *The Washington State Energy Code: Certification for Inspectors and Plan Reviewers for the Non-Residential Energy Code* at http://www.energycodes.gov/implement/documents/case_certify.doc for additional information.
  - The Springfield (OR) Utility Board (SUB) has enforced compliance with the non-residential energy code in Oregon as a service to the city, recognizing that non-compliance is a lost opportunity. They requested that the Bonneville Power Administration accept this Non-Residential Energy Code Enhancement program as a qualified research, development, and deployment measure eligible for full (dollar for dollar) conservation and renewable discount (C&RD) credit. On December 20, 2001, this proposal was formally accepted. As a result, the SUB has been involved in conducting plan review and inspection to ensure energy code compliance.
  - Utility rate variations could be offered wherein non-compliant buildings are charged more for their purchased energy. This would be determined by the utility or a third party acting on their behalf. This approach parallels the insurance industry with respect to building and fire code compliance, wherein insurance companies may provide reduced or increased insurance premiums based on an assessment of the building codes effective in the community and how well the community enforces those building codes.
  - A utility could set up a market to pay for additional compliance efforts in exchange for energy efficiency credits. Such an approach would require reliable information on code compliance, as well as the ability to measure and predict impacts.

- Utilities may charge an energy efficiency charge, which in turn could be used to help fund activities focused on increased energy compliance. As an example, Efficiency Vermont is funded via an efficiency charge and provides technical and financial incentives to Vermont households and businesses to help them reduce energy consumption. See http://www.efficiencyvermont.com/pages/Common/AboutUs/ for additional information. Also see the "Aligning Utility Incentives with Energy Efficiency Investment" subheading and linked report at http://www.epa.gov/cleanenergy/energy-programs/napee/resources/guides.html#guide2.

- **Local, State, and Federal Funding.** There may be an opportunity to use state, local, and federal taxes to continue funding programs initiated with Recovery Act funds. State matching grants could be made to local code agencies to augment existing resources.

- **Foundation Support from the Community.** Recently, the Community Foundation for Southeast Michigan awarded a grant to the Eight Mile Boulevard Association to enhance code enforcement along the boulevard. While not specifically related to energy code enforcement, this does provide an example of business and civic involvement in enhancing code compliance. Read more about the resulting partnership at http://eightmile.org/demo/demo/Html/8MBA_corridor_keeper_program.html.

- **Streamlining Processes.** Long-term labor savings can result from improvements in efficiency. For example, if permitting processes are made more efficient, the money saved may be applied to improved inspection processes. Perhaps the most obvious streamlining opportunity comes from automation. Recovery Act funding could be used to upgrade the computing environments and applications used by local jurisdictions, resulting in more efficient processes. The Alliance for Building Regulatory Reform in the Digital Age provides information and case studies on the savings available through more efficient building regulatory processes, including the following papers:
www.huduser.org/Publications/pdf/Bldg_Reg_Process.pdf
www.commerce.wi.gov/sb/docs/SB-WbsnWibleToolKit.pdf.

5.0 Onsite Compliance Evaluation Procedures

To help states effectively measure building energy code compliance, BECP has developed the following procedures, which include information and examples with respect to the populations, generation, makeup, and distribution of samples, as well as procedures for generating building and state compliance metrics.

5.1 Sample Populations

Since the energy codes apply to additions, alterations, and repairs to existing buildings, a representative sample of buildings throughout the state should include sampling of renovations in addition to new construction. BECP recommends compliance measurement procedures based on the evaluation of a statistically significant number of buildings in each of the following four building populations:

- residential new construction
- commercial new construction
- residential renovations
- commercial renovations.

BECP does not recommend that the state attempt to combine the four specific compliance metrics for an overall state compliance score, but instead recommends that the state report these compliance results separately. It is quite possible that a state will find that their compliance rate is above 90% in one metric (e.g., new residential construction), but does not attain 90% in another (e.g., commercial renovations). Reporting separate metrics for these four building populations provides some value in determining where activities that affect compliance may need to be strengthened.

While sampling of these four populations can be done during different years, BECP recommends performing the formal evaluation of a single population within a one-year time period. The statistical sampling process described in this section is based on estimates of construction during a one-year period, and should be adjusted if the evaluation of samples within one population is performed over a substantially longer time frame.

In most states, residential construction is defined as one- and two-family attached and detached dwellings, townhouses and multifamily structures three stories or less above grade and containing dwelling units (e.g., apartments, condominiums and cooperatives).[9] All other residential construction (hotels, motels, and dormitories of a transient nature), regardless of height, are considered commercial buildings as are all other non-residential buildings.[10] A simple way to differentiate residential buildings is through the building use group classification in most state or local building codes. For the purposes of energy code compliance, residential would include use group R-3, R-4, and any R-2 buildings not over

[9] In some states, such as Indiana and Wisconsin, low-rise multifamily buildings are subject to the commercial code. In these states, evaluations of such buildings can be based on the residential code, or the commercial code can be shown to be equal to or better than the residential code in the applicable locations. This topic is addressed in Section 2.3.

[10] In some states, small commercial buildings are subject to the provisions of the state residential energy code.

three stories in height above grade. All use group R-1 buildings and R-2 buildings over three stories in height are considered commercial buildings for the purposes of the energy code. Industrial buildings, where the primary use of energy is devoted to industrial processes, are not covered by the energy codes and are therefore not included in the compliance evaluation, although any commercial uses within such industrial buildings such as offices, cafeterias, and conference rooms would be considered commercial uses and those spaces could be potential subjects for evaluation.

Composing the sample of only new construction would not allow insight into how existing buildings are complying with the code. Both the 2009 IECC and 90.1-2007 provide definitions for repairs, alterations, and additions, along with information about the code's applicability to those modifications. While initially considering approaches for including renovations in the same sampling population as new construction, BECP has concluded that renovations are very different from new construction and will need to be sampled separately.

There are many different and often conflicting definitions for 'building renovation' several of which are described here for context. The two target building energy codes address renovations as follows:

- **Section 101.4.3 of the 2009 IECC** includes requirements for additions, alterations, renovations and repairs. Addition, alteration, and repair are defined in the 2009 IECC, but renovation is not. Section 202 of the IECC defines alteration as "*Any construction or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a mechanical system that involves an extension, addition or change to the arrangement, type or purpose of the original installation that requires a permit*" (ICC 2009).
- **Standard 90.1-2007** addresses additions and alterations only. The terms are both defined with additions subsumed in alterations, and explicitly exempting "*routine maintenance, repair, or service*" (ANSI/ASHRAE/IESNA 2007).

The Department of Defense's Unified Facilities Criteria document for Energy Conservation requires an entire building to be brought into compliance with code requirements for new construction if the renovation cost is 25% or more of the replacement cost of the building[3]. This definition adds a level of complexity to the issue by factoring in building valuation.

For the purposes of measuring code compliance, BECP recommends the following definition of renovations based on the above definitions, how building permits are typically issued and classified within a jurisdiction, and the need for a simple and accurate distinction between construction of new buildings and renovations to or within existing buildings:

- **Commercial Renovations:** Any work on or in existing commercial buildings where all or part of the work being performed is required to meet code and for which a permit was issued, including additions, alterations, and repairs
- **Residential Renovations:** Any work on or in existing residential buildings where all or part of the work being performed is required to meet code and for which a permit was issued, including additions, alterations, and repairs.

While one approach for determining compliance for renovations would be to include them with new construction, this creates an inequity in the derivation of a state metric. The energy impact of a minor alteration or small addition is not comparable to the energy impact of a new building. The evaluation methodology for new construction is based on evaluations of whole building samples, with each building receiving a compliance score. The evaluation of a subset of that building (such as a new mechanical system) would not be directly comparable.

Even among renovations, there exists a wide disparity in the impact that different renovations will have (e.g., a lighting retrofit vs. "gutting" the entire building shell). For these reasons, BECP recommends that renovations be sampled independently of new construction, and that the state metric be derived differently than for new construction. The methodology proposed in the following sections does not recommend assigning a compliance measurement to each individual renovation. Instead, the renovation samples will be evaluated as a group of observations (e.g., inspected code requirements), where some renovations will contribute only a few observations and some will contribute substantially more.

There are two types of renovations that could have been included with new construction; additions and renovations involving the gutting of the entire building shell (e.g., where the building modifications are extensive enough that the entire building becomes subject to the existing energy code). Additions, however, can be small (such as a single bedroom addition) and thus pose a similar problem in comparing their impact to that of a new building. Therefore, BECP recommends a simple split in evaluation methodology which separates all renovations that are permitted (including additions and those gutting the entire building shell) from new construction. This limits the data collection to two distinct categories, new construction and renovations, and simplifies identification of project type for the data collectors.

5.2 Generating the Samples

The following subsections provide procedures that may be used by states to generate an appropriate sample within each building population.

5.2.1 Sample Size

For most states, the BECP recommends a minimum sample size of 44 in each population. This recommended minimum number of buildings will vary by state, starting with a minimum of 44 buildings but incorporating fewer or more samples depending on the degree of building construction in each of the four building populations within the state. It should be noted that BECP's primary goal is to helps states estimate building energy code compliance rates. However, there are two competing secondary goals:

- to identify a process that meets the primary goal in a cost-efficient manner
- to gather data that allows further analysis of unique attributes within each state.

In these recommendations, BECP has leaned heavily toward providing a cost-efficient method for meeting the primary goal, and has therefore recommended minimal sample sizes. If a state wishes to have enhanced estimates of compliance rates for specific climate zones, jurisdictions, utility areas, or buildings with specific attributes, then a larger sample of buildings within that state will be necessary to achieve the latter secondary goal.

Equation 5.1 can be used to identify an appropriate sample size for a one-sided confidence interval (Gilbert 1987). Typical two-sided confidence intervals give the mean of the sample and then provide a margin of error above and below that sample mean, where the true population mean could exist with a prescribed confidence (e.g., the proportion of the population voting for candidate A is 52% ± 3% with 95% confidence). One-sided confidence statements are only interested in one side of the range; in this case the higher range is of interest. The two-sided equation is very similar to the one-sided equation, but requires a slightly larger sample size.

Equation 5.1

$$n = \frac{S^2\left(Z_{(1-\alpha)} + Z_{(1-\beta)}\right)^2}{\Delta^2} + 0.5Z^2_{(1-\alpha)}$$

where: n = the number of buildings that must be evaluated from the state

s^2 = the square of the standard deviation (sample variance)

Z = a standard normal score from a normal distribution

$1-\alpha$ = the confidence level

$1-\beta$ = the power

Δ (delta) = the minimum true difference from 90% that is important to correctly detect as being different from 90% (i.e., the detectable difference)

Typically, an $\alpha = 0.05$ and $\beta = 0.2$ are used and have been assumed for this effort. BECP has also identified the value for Δ as 5%. The average state building compliance rate can be between 0 and 100% and have standard deviation estimates as large as 50%. To identify an appropriate standard deviation estimate, *s*, for this study, BECP evaluated a range of different scenarios when a state's building compliance score is close to 90%. Based on this evaluation, an estimated standard deviation of 13 percent was selected and is believed to be a conservative estimate (note that the variance is $s^2=13^2$).

The final statistical confidence statements will provide each state with the ability to say, "The state of XXX is 95% confident that the upper confidence bound of the building compliance rate is YY% + ZZ%." If the resulting upper confidence bound is above 90%, BECP concludes that the sample of buildings gives some evidence (with prescribed confidence level) that the state has demonstrated a 90% compliance rate.

For example, State A and B went through the entire process of a random sampling (n=44 for this example), data collection, and data summarization. State A had an average building code compliance rate of 82% and a standard deviation estimate of 12% and State B had an average building code compliance of 87.5% and an estimated standard deviation of 15%. Using Equation 5.2, with a confidence level = 95%, the upper confidence bound is calculated using the following equation,

Equation 5.2

$$\bar{x} + 1.645 \times \frac{s}{\sqrt{n}}$$

where:

$\bar{x}$ = the mean

s = the standard deviation

n = 44 (the number of buildings in the sample)

State A would report an upper confidence bound of their compliance rate as 84.98%:

$$82\% + 1.645 \times \frac{12\%}{\sqrt{44}} = 84.98\%.$$

State B would report an upper confidence bound of their compliance rate as 91.22%:

$$87.5\% + 1.645 \times \frac{15\%}{\sqrt{44}} = 91.22\%$$

State A's upper confidence bound provides some evidence that their compliance rate is below 90% with 95% confidence, and would therefore not meet a 90% compliance target. State B's upper confidence bound of 91.22% provides some evidence that they would meet the 90% compliance goal.

The final confidence interval is based on the calculated standard deviation from the actual state sample and not the assumed standard deviation used in defining the sample size (which was assumed to be 13% in the previous section). BECP has attempted to make conservative assumptions about the standard deviation observed in the compliance rates from the sample of buildings and expect most standard deviations to be smaller.

It is understood that the standard deviation from a state's sample of buildings is an estimate and some allowance will be made for this fact. Thus, the result of a state's sample standard deviation can be as high as .16 and be acceptable. If the standard deviation estimate resulting from the state sample is above .16 and the upper confidence bound is above .9, then additional samples based on the estimated standard deviation will be necessary to ensure a valid sample. The number of additional samples, which can be determined from Equation 5.2 using the state's revised estimate for *s*, will then be incorporated into the state's building compliance upper confidence calculation.

Figure 5.1 shows the different sample size requirements as a function of the assumed standard deviation estimates. BECP assumed sample size is labeled on the graph.

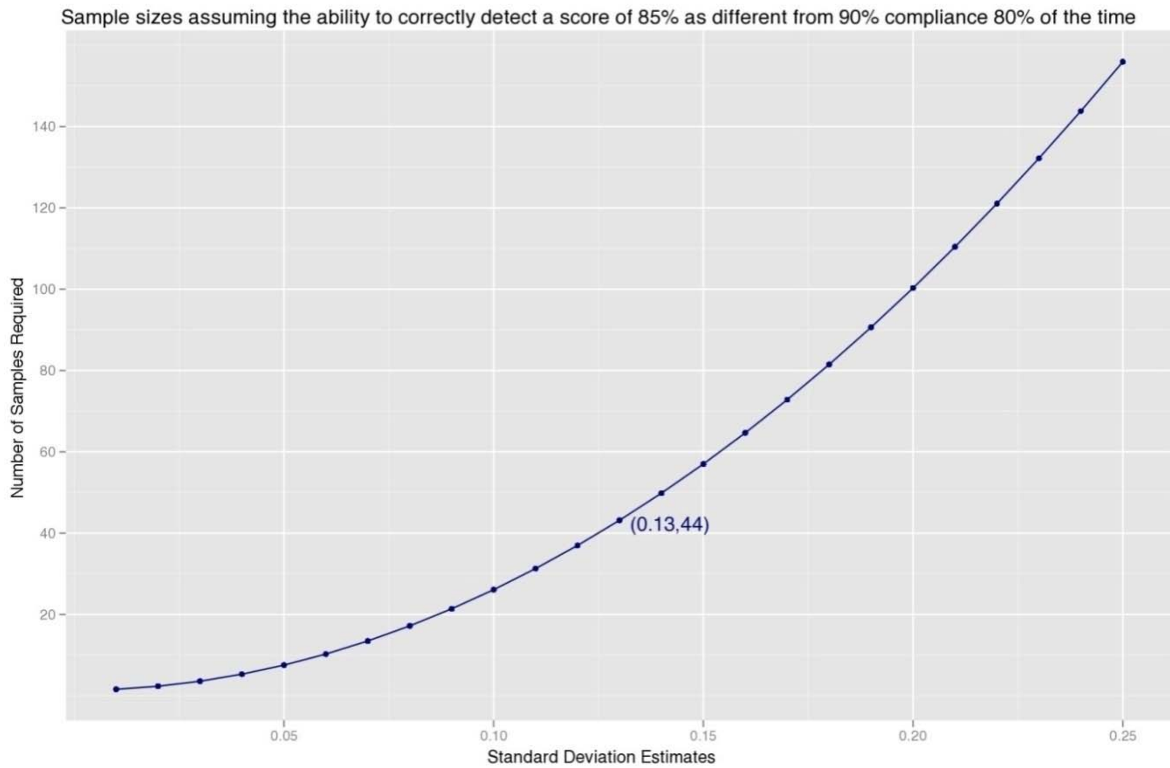

Figure 5.1. Graph of the required sample sizes based on different standard deviation estimates. BECP assumed standard deviation is labeled on the graph.

5.2.1.1 Renovations

The necessary number of renovations required for an estimate of the compliance rate within a tolerable margin of error for renovations is dependent on an understanding of the correlation between checklist items within the buildings sampled as well as the variability in the number of checklist items being evaluated for each building. While the standard deviation assumptions for renovations may not be the same as new construction, BECP believes that the parameters assumed for new construction are reasonable for renovations. Thus, BECP is proposing a minimum number of buildings evaluated to be 44 for residential renovations and 44 for commercial renovations.

5.2.1.2 New Commercial Buildings

BECP has identified three commercial building size strata (small, medium, and large) which should be sampled in every state, and two additional commercial building size strata (X-large and XX-large) which should be included where appropriate. The recommended size strata boundary definitions are the following:

- Small: 1-2 stories, single zone, up to 25,000 ft^2 in conditioned floor area
- Medium: Larger than 25,000 ft^2 and up to 60,000 ft^2
- Large: Larger than 60,000 ft^2 and up to 250,000 ft^2

- X-Large: Larger than 250,000 ft^2 and up to 400,000 ft^2
- XX-Large: Larger than 400,000 ft^2.

The small building criteria limit of 25,000 ft^2 and 1-2 stories corresponds with the code criteria delineating simple and complex mechanical systems (Section 6.3.1 of 90.1-2007). The X-large and XX-large limits have been used by the census in previous studies (Census Bureau 1999).

Section 5.2.1 indicated that the building populations will vary by state. The sample size derivation for commercial buildings assumes that 44 samples will be drawn from the small, medium, and large size strata, but this sample size may increase for states with X-large and XX-large buildings, and may decrease for states with less new commercial construction.

5.2.1.3 X-Large and XX-Large Commercial Buildings

In some states, additional commercial building samples may be required from the X-large and XX-large strata, which are composed of very large commercial buildings. The number of observations in these strata will vary, depending on the state. Equation 5.3 is used to determine how many X-large and XX-large samples are required. The maximum number of necessary buildings sampled in each of these larger strata would be 14. Equation 5.3 identifies the lower adjusted sample size based on the total number of expected buildings in each of the two strata (Cochran 1977).

Equation 5.3

$$n_{adjusted} = \frac{n}{1 + \left(n/N \right)}$$

where: $n_{adjusted}$= the adjusted number of required samples, rounded up to the nearest integer
n = the original sample size estimated
N = the total number of buildings expected to be in the study period population

For example, in Washington State, a total of 15 X-large buildings and 10 XX-large buildings are expected in the upcoming evaluation year. Equation 5.4 is used to determine the samples in each stratum, resulting in a sample of 8 buildings in the X-large stratum and a sample of 6 buildings in the XX-large stratum.

Equation 5.4

$$n_{\text{X-Large}} = \frac{14}{1 + \left(14/15 \right)} = 7.24 \qquad n_{X\text{X-Large}} = \frac{14}{1 + \left(14/10 \right)} = 5.83$$

Thus the X-large stratum would consist of a sample of 8 buildings and the XX-large stratum would consist of 6 buildings. Figure 5.2 demonstrates the relationship between the number of necessary buildings to sample (n) and the total number of buildings (N) within the stratum. The black dots identify the different rounded-up adjusted sample sizes for a range of expected total number of buildings where 14 buildings was the maximum sample required.

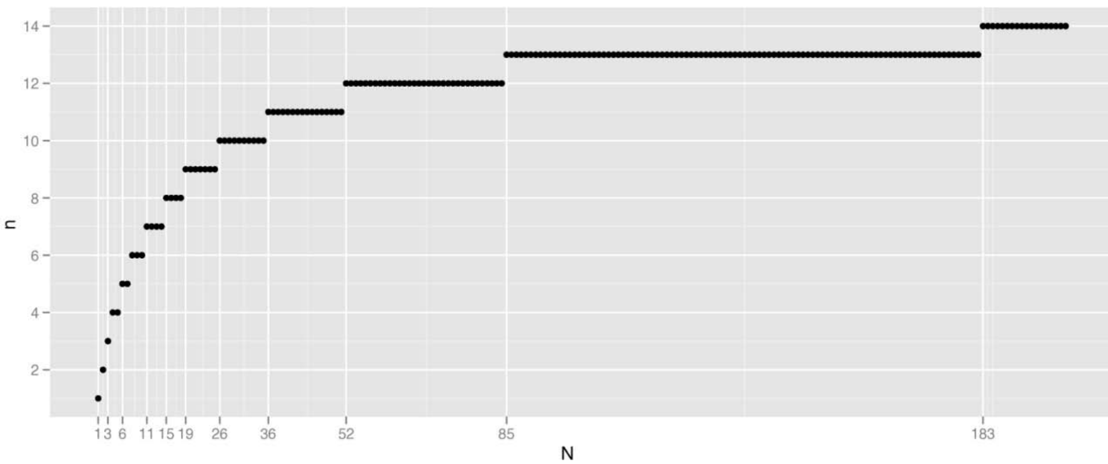

Figure 5.2 Relationship between the maximum number of buildings to sample (n) and the total number of buildings (N) within the stratum.

We should note that BECP does not recommend that the two larger building size strata be allocated by climate zone, as was recommended for the small, medium, and large strata. Very large buildings are typically found in highly urban areas, and the samples will by necessity be drawn from those areas. It is left up to the state to identify areas most likely to contain these samples, but BECP is available to help with this identification based on evaluating commercial building starts for very large buildings from previous years.

5.2.1.4 Small Population Sample Size Adjustment

The same methodology presented in the previous section for X-Large and XX-Large buildings also applies when generating an adjusted sample for the 44 buildings in each of the four populations. In less populated states, such as North Dakota or Wyoming, which do not have a large population of constructed buildings to study in any given year, this adjustment can be applied to each of the four compliance populations. A less populated state could use the total number of buildings built in the previous year as an estimate of the expected population for the study period. For example, Equation 5.5 identifies the sample size necessary for one of the four building populations with an estimated total of 221 buildings (*N* in Equation 5.3). Thus, 37 observations would be the minimum sample required for this population in the state.

Equation 5.5

$$n_{adjusted} = \frac{44}{1 + \left(44 / 221 \right)} = 37$$

5.2.2 Sample Distribution

This section defines a procedure for how a valid random sample is distributed across the state and, for commercial new construction only, includes distribution by building size strata. The process relies on use of the most recent annual building starts or permitting data, such as F.W. Dodge (Dodge) data for commercial buildings, or census data for residential buildings. BECP has access to several data sources that can be used in generating and distributing a random sample according to the process described in this section, and anticipates providing support and tools to states to assist in generating the statistics shown below and in selecting sample sets for this effort.

To provide some assurance that the sample of buildings from each state represents the different climate zones, jurisdictions, and population densities appropriately, BECP is proposing the spatial distribution of samples be allocated according to the sampling process described in this section. This process should assure that the majority of the buildings evaluated are from the regions that represent the majority of new construction within each state and maintain the necessary statistical sampling properties.

The following explanation shows how the process can be done for the 44 commercial buildings to be sampled in the small, medium, and large size strata within a state. The sample distribution algorithms provided are based on estimating future building starts based on averaging the building starts over the three previous years. Where there are reasons to assume that one of the previous three years is not a good indicator of future construction trends, the three-year average could be derived differently. For example, data from the previous year only might be used if there are indications that trends from the previous year will continue. The estimated three-year average used in the following examples for commercial buildings was developed using Dodge data. Other data sources, such as census permitting data, could also be used.

5.2.2.1 Distribution Across Commercial Building Size Strata

Mechanical system code requirements for commercial buildings vary for simple vs. complex buildings (see Section 6.3.1 of 90.1-2007). The distinction between simple and complex buildings is closely correlated to building size. Other code requirements are also impacted by building size. For this reason, the BECP recommends that the main sample of commercial buildings (44 from each state) include commercial buildings that are distributed equally within the three main building size strata defined in Section 5.2.1.2 (small, medium, and large), resulting in 14-15 samples to be taken from each of the three main size strata. There may be cases in which few buildings are constructed within a specific building size stratum that will necessitate the sample of buildings to be taken more heavily, if not completely, from the stratum which have the bulk of buildings of that size. For example, if a state has very limited new commercial construction in the large stratum, the majority of the samples would have to be taken from the small and medium strata.

5.2.2.2 Distribution Across Climate Zones

In recommending how samples should be distributed, BECP notes that the code requirements vary by location and building type. Envelope code requirements vary by climate zone,[11] as do commercial building economizer requirements. Additionally, code enforcement in different geographical locations is performed by different jurisdictions, which can impact compliance rates. To provide some assurance that the sample of buildings from each state represents the different climate zones, jurisdictions, and population densities appropriately, BECP is proposing the spatial distribution of samples be allocated according to the sampling process described in the following sections. This process should assure that the

[11] Throughout this document, 'climate zone' refers to the numerical zones shown in Figure 5.3. They do not refer to the additional delineation of zones based on moist, dry, and marine climates.

majority of the buildings evaluated are from the regions that represent the majority of new construction within each state and maintain the necessary statistical sampling properties.

The climate zones (see Figure 5.3) defined in the energy code(s) will be used along with the average number of new building starts in each climate zone to identify the sample distribution. If a state has multiple climate zones, the building samples will be distributed across climate zones based on the average number of building starts over the three previous years according to the following routine. For commercial new construction, 14-15 samples in each main size strata (small, medium, and large) will be distributed across the state's climate zones according to the following steps. For new residential construction and all renovations, 44 samples will be distributed across the climate zones.

1. Calculate the average number of building starts for the previous three years in each climate zone within the state.
2. Calculate the proportion of building starts in each climate zone and remove any climate zones with a proportion smaller than .02 (i.e., 2%).
3. Calculate the number of samples for each included climate zone, excluding the most densely populated climate zone, by multiplying each proportion by the total number of samples (*n*) and round up to the nearest integer.
4. The number of samples for the most densely populated climate zone is the total number of samples minus the sum of the numbers calculated in Step 3.

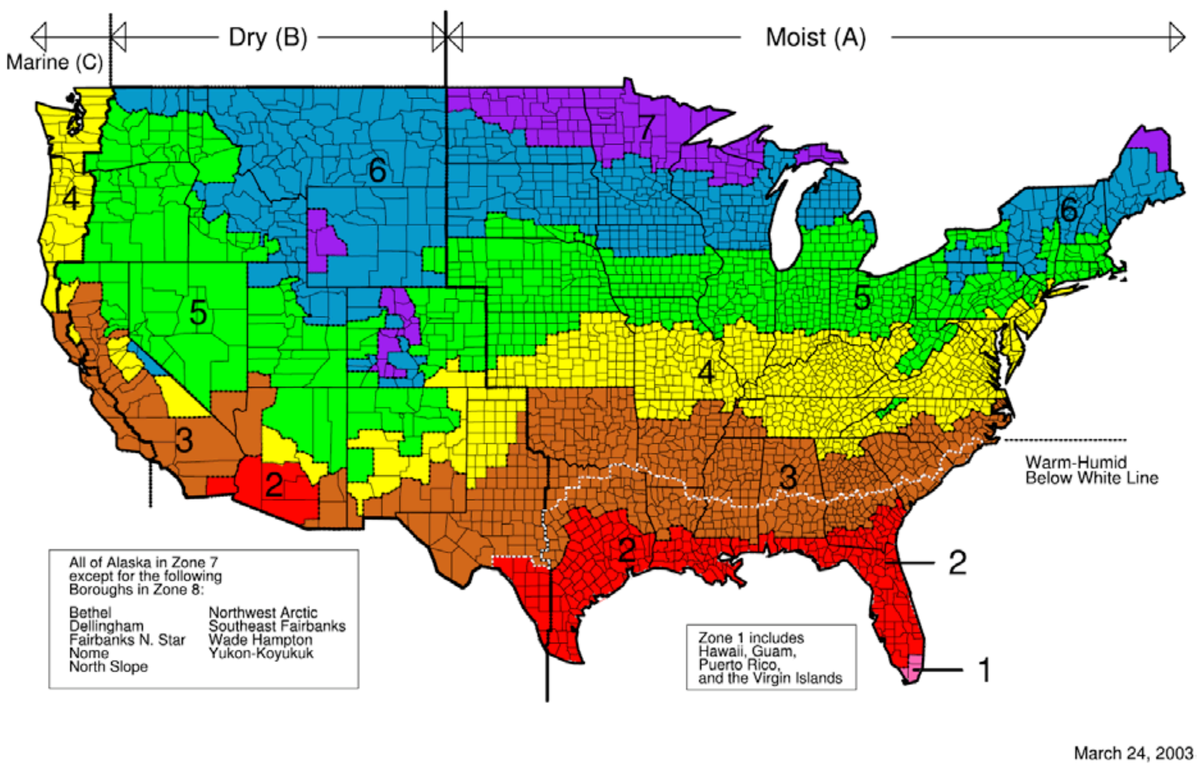

Figure 5.3. Map of the DOE climate zones for the United States

The following example demonstrates an application of this approach for the commercial building evaluation in the state of Washington. Table 5.1 shows the expected number of buildings within each of the three main building size strata and within each climate zone within the state of Washington. This is the information that would be obtained from Steps 1 and 2 above. Note that Climate Zone 6 is removed from consideration because the building starts in all size strata are less than 2%.

Table 5.1. Building starts per year in the three main strata, by climate zone, for Washington State. Strike-out values identify climate zone size strata that will not be included in the sample.

Climate Zone	Small Stratum Building Starts and %	Medium Stratum Building Starts and %	Large Stratum Building Starts and %
All	790 (100%)	133 (100%)	180 (100%)
4	637 (80.6%)	111 (83.5%)	162 (90%)
5	147 (18.6%)	20 (15%)	18 (10%)
6	~~6 (0.8%)~~	~~2 (1.5%)~~	~~0 (0%)~~

Table 5.2 shows how the 15 samples in the small stratum for the state of Washington would be spread across Climate Zones 4 and 5 (12 and 3 samples respectively) and represents Steps 3-4 above. Tables 5.3 and 5.4 demonstrate the results for the medium and large size strata.

Table 5.2. Example of commercial building sample allocation for the small building stratum, by climate zone, in Washington State.

Climate Zone	Building Starts Small Strata	Proportion of Statewide Average	Stratum Sample Size (n)	Climate Zone Sample Size for Small Strata
4	637	0.806	15	12
5	147	0.186	15	3
6	6	0.008	15	Removed

Table 5.3. Example of commercial building sample allocation for the medium buildings stratum, by climate zone, in Washington State.

Climate Zone	Building Starts Medium Stratum	Proportion of Statewide Average	Stratum Sample Size (n)	Climate Zone Sample Size for Medium Stratum
4	111	0.835	15	12
5	20	0.15	15	3
6	2	0.015	15	Removed

Table 5.4. Example of commercial building sample allocation for the large buildings stratum, by climate zone, in Washington State.

Climate Zone	Building Starts Large Stratum	Proportion of Statewide Average	Stratum Sample Size (n)	Climate Zone Sample Size for Large Stratum
4	162	0.90	14	12
5	18	0.10	14	2
6	0	0.0	14	Removed

After the process is repeated for each stratum, Climate Zone 4 will have a sample of 36 buildings, with 12 buildings sampled from each size stratum. Climate Zone 5 will have a sample of 8 buildings, with 3 buildings sampled from the small and medium size strata and 2 from the large. Climate Zone 6 would not have any samples allocated.

Figure 5.4 illustrates the average number of building starts for each size stratum separated by climate zone, representing a 3-year average of the Dodge data for Washington State. This type of summary may be helpful to estimate if there will be enough expected buildings from which to sample within each building size stratum in each climate zone. In this example, it appears feasible that 12 buildings could be evaluated from each stratum in Climate Zone 4, and 2-3 buildings from each stratum in Climate Zone 5.

Finding buildings for evaluation in the large building stratum may be the most difficult, and these may need to come primarily from the large metropolitan areas within each climate zone. In contacting jurisdictions to prepare for an onsite visit, the evaluators may want to ask if multiple large, commercial buildings are currently being constructed. This information should be taken into consideration when selecting buildings from each climate zone within each size stratum.

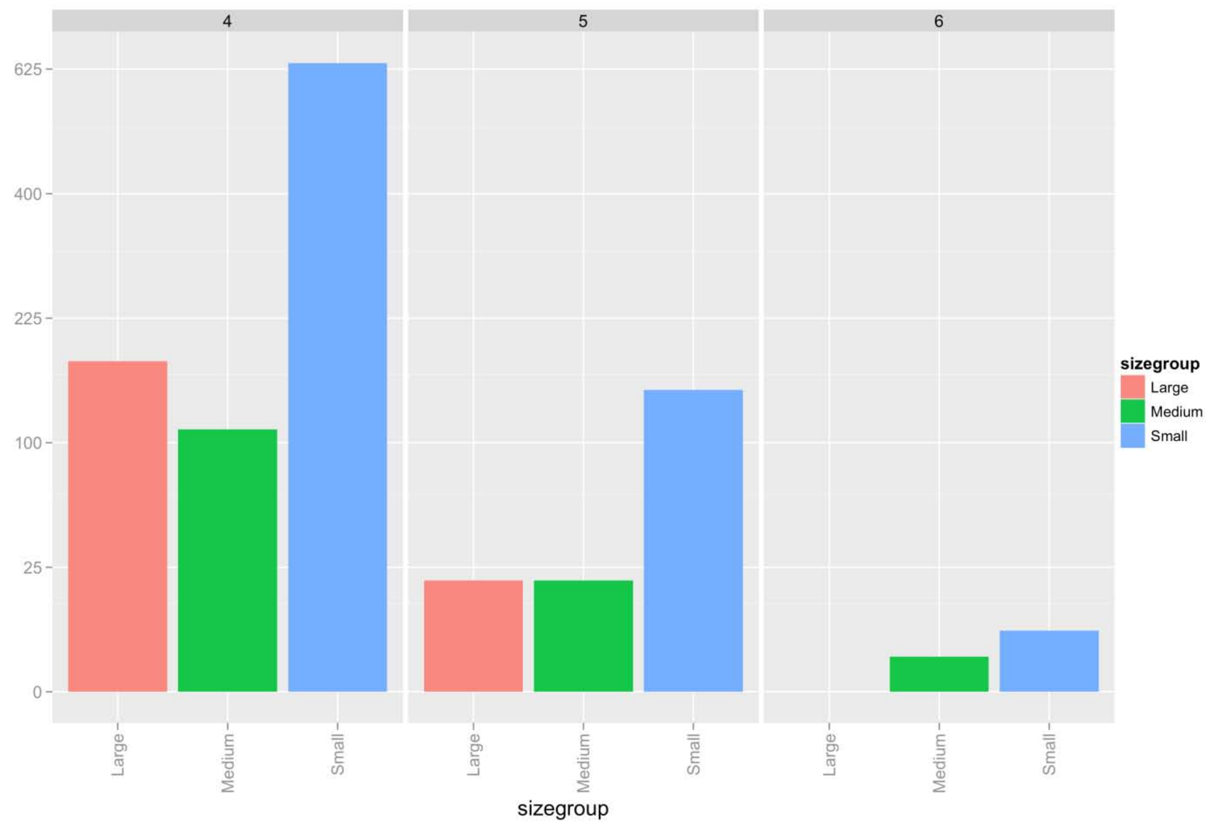

Figure 5.4. Number of buildings in each size stratum separated by climate zone. Note that the y-axis is distorted (i.e., not evenly spaced) to visualize the low count numbers.

5.2.2.3 Distribution Across Counties

The next stage of the sample distribution will identify how many buildings within each county must be evaluated, with a desire to sample more heavily in counties expected to have the most building starts in the upcoming year. BECP is recommending these procedures to determine the number of samples per county, recognizing that multiple jurisdictions may have authority in a single county. Data sources, such as Dodge, typically provide statistics by city and/or county rather than by the building jurisdictions having authority over construction. For this reason, the allocation of the samples to the multiple jurisdictions within the county is left to the state and/or their contractors to implement. In choosing jurisdictions to evaluate, there is an assumption that states and/or evaluators will contact local jurisdictions prior to visiting that jurisdiction in order to determine what samples are available for evaluation. If any local jurisdiction does not have a permitting agency, evaluations cannot easily be done in that jurisdiction for several reasons:

- It will be difficult, if not impossible, for the desired building samples to be located.
- For renovations, part of the definition being proposed for renovations includes the issuing of a permit for that renovation.

Ignoring jurisdictions without a permitting agency may introduce some bias to the results, as these jurisdictions may tend to have lower code compliance. For this reason, BECP does recommend that such jurisdictions be documented in reporting state compliance.

For each included climate zone, the process to identify sample allocations across counties in that climate zone is as follows:

1) Using the average number of building starts based on the previous three years, identify the number of building starts for each county. For commercial buildings, identify building starts within each building size strata for each county.
2) Remove any counties with an average building start value of less than 2 buildings.
3) Create a list of counties, where each county is included in the list as many times as the number of building starts calculated in Step 2.
4) Randomly select the number of buildings needed from the list created in Step 3, and summarize how many samples were chosen from each county. Random selection can be from an automated process, using functions in a spreadsheet, or simply by pulling county names from a hat.

The state of Washington will again be used as an example of this process for commercial buildings, with recent Dodge data used to estimate the building start activity. Figure 5.5 depicts the three climate zones in Washington and the average building starts within the medium building stratum in each county. In this figure, colored regions identify the three climate zones, and the red dots identify the largest cities in Washington, with the size of the dot representing the number of building starts in that city. The data from Climate Zone 5 (the green region in Figure 5.5) is used to demonstrate this process.

Based on Table 5.1 and Figure 5.5, Climate Zone 5 is expected to have an annual total of 20 new commercial building starts in the medium size stratum, spread throughout the 17 counties. Table 5.5 shows the 17 counties in Climate Zone 5 and the expected number of commercial building starts by county. The information from this table is used to create the list of counties as described in Step 3 and is shown in Table 5.6. Finally, a random sample of three county labels is selected from the list, shown in Table 5.7, which identifies the buildings to be sampled from the medium size stratum in Climate Zone 5. In this example, all three samples were randomly selected to be taken from Spokane County.

This process is then repeated for each building size stratum and climate zone combination. For the state of Washington this process would be done 9 times (3 climate zones and 3 main building size strata).

An example of the county locations of a sample of 44 commercial buildings within Washington State is summarized at the end of this section in Table 5.8. Note that Washington State does have new construction in the X-large and XX-large strata that would need to be sampled as well.

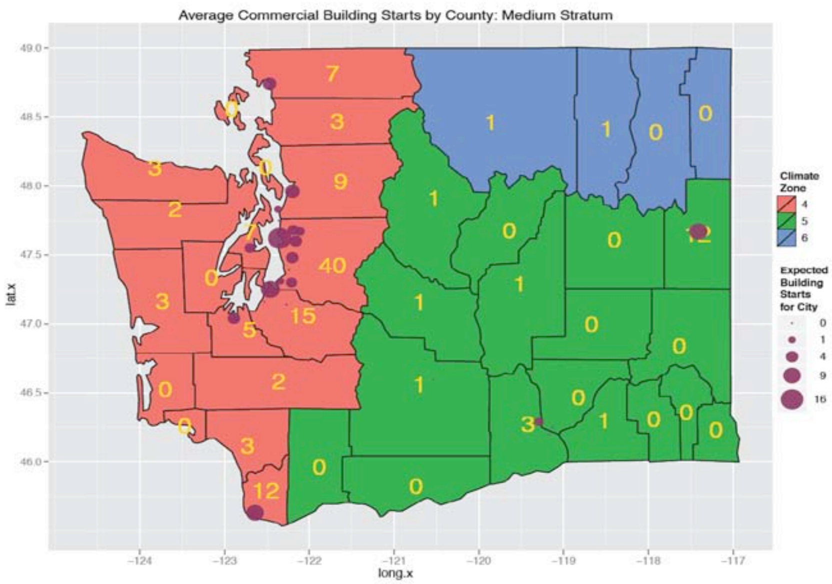

Figure 5.5. Building start data for the medium stratum by county for the state of Washington

Table 5.5. Commercial building starts in the medium size stratum for Climate Zone 5, by county. Strike-out values identify counties which were excluded from consideration.

	Adams	**Asotin**	**Benton**	**Chelan**	**Columbia**	**Douglas**	**Franklin**	**Garfield**	
Building Starts	~~0~~	~~0~~	3	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	
	Grant	**Kittitas**	**Klickitat**	**Lincoln**	**Skamania**	**Spokane**	**Walla Walla**	**Whitman**	**Yakima**
Building Starts	~~1~~	~~1~~	~~0~~	~~0~~	~~0~~	12	~~1~~	~~0~~	~~1~~

Table 5.6. List of county names where each included county is repeated based on the numbers shown in Table 5.5.

List of County Names				
Benton	Spokane	Spokane	Spokane	Spokane
Benton	Spokane	Spokane	Spokane	Spokane
Benton	Spokane	Spokane	Spokane	Spokane

Table 5.7. List of three counties randomly selected for samples in the medium stratum in Climate Zone 5 for Washington State.

Randomly Selected County Samples		
Stratum	**Climate Zone**	**County**
Medium	5	Spokane
Medium	5	Spokane
Medium	5	Spokane

Table 5.8. Final random selection of county labels from each climate zone (left) and the final summary of the number of buildings identified to be sampled in each selected county (right).

List of 44 County Labels		
Stratum	**Climate Zone**	**County**
Small	4	Cowlitz
Small	4	Whatcom
Small	4	King
Small	4	King
Small	4	King
Small	4	Pierce
Small	4	Pierce
Small	4	Pierce
Small	4	Skagit
Small	4	Snohomish
Small	4	Snohomish
Small	4	Clark
Small	5	Spokane
Small	5	Yakima
Small	5	Yakima
Medium	4	King
Medium	4	King
Medium	4	King
Medium	4	King
Medium	4	King
Medium	4	King
Medium	4	King
Medium	4	Clark
Medium	4	Clark
Medium	4	Pierce
Medium	4	Thurston
Medium	4	Whatcom
Medium	5	Spokane
Medium	5	Spokane
Medium	5	Spokane
Large	4	Pierce
Large	4	Pierce
Large	4	Snohomish
Large	4	King
Large	4	King
Large	4	King
Large	4	King
Large	4	King
Large	4	King
Large	4	King
Large	4	King
Large	4	Clark
Large	5	Benton
Large	5	Spokane

Building Sample Allocation		
County	**Buildings (small/medium/large)**	**Total Buildings**
Benton	1 large	1
Clark	1 large, 2 medium, 1 large	4
Cowlitz	1 small	1
King	8 large, 7 medium, 3 small	18
Pierce	2 large, 1 medium, 3 small	6
Skagit	1 small	1
Snohomish	1 large, 2 small	3
Spokane	1 large, 3 medium, 1 large	5
Thurston	1 medium	1
Whatcom	1 medium, 1 large	2
Yakima	2 small	2
TOTAL		44

5.2.3 Sample Make-Up

Once the state has determined the number and distribution of residential and commercial buildings that must be included in the compliance assessment, care should be taken to ensure the buildings selected represent a reasonable cross section of the building types within the state. A reasonable cross section of buildings, both residential and commercial, should consider the building use, ownership, and design. Building use considers the activities or function of the building. Building ownership pertains to whether the building is likely to be owned and/or operated by state or local government vs. the private sector, and whether the final occupants will be responsible for the utility payments. Since factors affecting residential and commercial buildings are quite different, these building attributes are discussed separately in the following sections.

Optimally, all building attributes would be covered in the sample across the state. The sample from each state is not intended to provide a clear understanding of compliance rates for each building type, but to be a representative sample of the different building types within the state. In other words, some precautions should be taken to make sure that the sample of buildings is not biased towards one of the attributes described in the following sections. A residential compliance assessment based on evaluating only new, single-family homes would not be considered a representative sample of residential buildings in the state, since the residential codes apply also to multifamily buildings. Equally non-representative would be including only retail buildings in an assessment of commercial building compliance.

Recognizing that some buildings of a given type might not be available in a given state, the state should attempt to select from as varied a sample set as possible. Some characteristics to consider in generating sample sets with good distributions of building attributes are provided in subsequent sections. BECP suggests that all pertinent meta-data described in the following sections be included with each building in the state sample. This information will help each state demonstrate that its sample is not biased and provide valuable information for future nationwide studies.

5.2.4 Commercial Building Attributes

The relevant commercial building attributes (use, ownership, size, and complexity) states may consider while generating samples are discussed in the following subsections.

5.2.4.1 Commercial Building Use

Various codes and classification systems provide different building use types and naming conventions. For simplicity and to facilitate identification consistent with state and local building codes, the following simplified list of commercial building use types is proposed. These commercial designations represent a consolidation from sources such as the International Building Code, ASHRAE Standard 90.1, the New Buildings Institute (NBI) Core Performance document, Commercial Building Energy Consumption Survey (CBECS) Principle Building Activities, and an NBI-funded study of commercial energy code compliance in the Pacific Northwest. When developing a sample set for commercial buildings, the inclusion of samples from a range of these use types is recommended.

- Office **-** workplace and working environment primarily for administrative and managerial workers
- Retail/Mercantile **-** buildings for the sale of goods or merchandise from a fixed location

- Warehouse/Storage - building for storage of goods
- Education/School - institution designed to allow and encourage students (or "pupils") to learn, under the supervision of teachers
- Lodging/Hotel/Motel - an establishment that provides paid lodging on a short-term basis
- Restaurant/Dining/Fast Food - an establishment that prepares and serves food and drink to customers
- Public Assembly/Religious - a building where people congregate
- Healthcare - institution for health care providing patient treatment by specialized staff and equipment, and often but not always providing for longer-term patient stays
- High Rise Residential - a building containing multiple dwelling units intended for non-transient occupancy such as an apartment or condominium

The state sample could also include mixed use residential and commercial buildings, such as a low-rise multifamily building with office, conference, exercise, retail and/or other commercial uses within the building. In this case, the portion of the building considered residential would be included in the residential sample and the portion of the building considered commercial would be included in the commercial sample. This would comprise two separate samples, one for the residential sample set and one for the commercial sample set.

5.2.4.2 Commercial Building Ownership

Some building types, such as schools, are more likely to be owned and operated by state or local government and as such they would be more inclined to be in compliance with state or local codes because the owner has a vested interest in the owning and operating costs and is under public scrutiny. A building sample that contained only owner designed, constructed and occupied structures could skew the results toward increased compliance. Similarly, a sample that looked only at speculative commercial properties could skew the results toward decreased compliance based on the assumption that speculative construction may focus more on first cost than life cycle cost. National accounts such as hotel chains or retail companies may be more inclined to comply as a matter of corporate direction and to increase their ability to compete with others in their market segment. In developing a cross section of buildings to include in the compliance assessment, states should consider corporate/real estate investment trusts, buildings owned or funded by state or local government, national accounts and speculative ownership scenarios.

5.2.4.3 Commercial Building Size and Complexity

Building design, system type, and building size may affect the application of energy code provisions to a building. These design issues are driven by the code requirements which vary based on window wall ratio; type of service systems, equipment and controls; and complexity of lighting systems and controls. For example, there are different code requirements for a building with one or two separate zones that are served by one or two separate rooftop HVAC units, and a building that is served by a large central chiller and variable air volume system and temperature controls. In developing a representative cross section of commercial buildings the state should identify the provisions in the code that vary by design. At a minimum, when complying with 90.1-2007, these delineations include:

- Building Window-to-Wall Ratio. Buildings with a window wall ratio above 40% and/or skylight area above 5% may not use Section 5.5 of 90.1-2007, the Prescriptive Building Envelope Option.
- Simple vs. Complex HVAC Equipment. There are different requirements for simplified vs. complex HVAC systems, as defined in Section 6.3 of 90.1-2007. Simple systems serve one zone, have unitary equipment and a singular thermostat, the outdoor air capacity is less than 3,000 cfm, and reheat or simultaneous heating and cooling are not possible. Complex systems would be those that are not simple systems.
- Simple Lighting Systems and Controls. Simple lighting systems could be considered those where compliance is evaluated under the lighting power density provisions in the code for an entire building type, as opposed to a space-by-space calculation. Simple systems have relatively simple controls strategies (e.g., daylighting tradeoffs and occupancy sensors are not required).

Some of these delineations are already partially considered by ensuring that commercial buildings are selected equally from the previously defined size strata.

5.2.5 Residential Building Attributes

The relevant residential building attributes (use, ownership, size, and complexity) states may consider while generating samples are discussed in the following subsections.

5.2.5.1 Residential Building Use

Residential building use groups that should be included in the sample set include modular homes, site-built single-family detached or attached homes, townhouses, and multifamily buildings (apartments and condominiums). Modular homes, while single-family dwellings, are typically regulated at the state level and are inspected in part at the factory. This difference in construction method and code enforcement in comparison to site-built residential buildings suggests that modular homes be specifically identified and included in the sample. The following list of residential building use types are recommended to be included in the sample set:

- Modular homes
- One- or two-family detached dwellings
- One- or two-family attached dwellings
- Townhouses
- Multifamily apartments
- Multifamily condominiums.

5.2.5.2 Residential Building Ownership

Building ownership is likely to play a role in compliance for low-rise multifamily buildings. For example, there may be an increased incentive for a condominium developer to comply with the code than an apartment developer because of utility payment scenarios once the building is occupied. In the former case, owners purchasing the unit are more likely to be interested in energy efficiency and utility costs compared to those who are not investing in the property but instead simply renting on a transient basis. States might also consider differences between speculative owner/tenant scenarios vs. owner occupied (purchaser) scenarios.

5.2.5.3 Residential Building Size and Complexity

Size differentiation is less important for residential buildings than for commercial, as the residential code provisions are almost identical regardless of the building size. A few requirements for multifamily buildings may vary depending on whether individual service equipment and systems serve each dwelling unit or central service equipment and systems are used. Size distinctions between single-family and multifamily dwellings are for the most part covered by the variations in building use proposed in Section 5.2.5.1.

5.2.6 Attributes of Renovations

For new construction, BECP provided recommendations that buildings within the sample set vary based on attributes such as building use and ownership scenarios. Similarly, the renovations sample set should be comprised of a variety of renovation types. A varied sampling of renovation projects should include buildings where:

1. All of the following systems are replaced, or become subject to the current energy code (such as a change in occupancy or an entirely gutted building):
   - Building envelope insulation
   - Horizontal and vertical fenestration
   - HVAC system
   - Lighting system
   - Service water heater system
2. Conditioned space/structure was added
3. Unconditioned space was added to conditioned space, such as the conversion of a portion of an unconditioned warehouse to an office, or an attic space to a bedroom
4. A complete HVAC system was added or replaced
5. Ductwork was added or replaced
6. HVAC controls on an existing system were replaced
7. 50% or more of the lighting systems were replaced or lights were added to an existing system
8. Lighting controls on an existing system were replaced
9. Floor-to-ceiling partitions were constructed to create new spaces within a building, and lighting controls were added to meet the switching requirements
10. Lighting fixtures on the exterior of a commercial building were changed out.

Minor repairs, replacements in kind, and similar items as listed in the IECC and 90.1 should not be included in the renovations samples. In some cases these are items where a permit is not required and as a result are not subject to the energy code. In other cases, the repair or replacement is clearly not significant in relation to the remainder of the building and as such, while it must satisfy the code, non-compliance would have a nominal impact on the compliance rating of the state.

5.3 Generating Building Metrics

The following subsections comprise a discussion on how to generate an effective building metric while evaluating compliance with building energy codes.

5.3.1 Alternative Approaches

Once the appropriate number, distribution, and makeup of samples are obtained for each of the four building populations, these new and renovated building spaces must be evaluated. For this step, there are two proposed approaches were considered:

- **Method 1.** Evaluated buildings either pass or fail the energy code evaluation, and the percentage of buildings within the state that are deemed to comply is reported. For example, if 90% of the buildings sampled in the state receive a passing score, the reported metric is 90%.
- **Method 2.** Evaluated buildings are each assigned a compliance rating of 0–100% based on the proportion of code requirements that each has met, and the evaluated buildings' scores within a state are averaged to derive an overall compliance metric with an associated confidence.

In evaluating these two approaches, BECP considered the goals and desired outcomes of the Recovery Act and SEP objectives, as well as the logistics of undertaking such compliance measurement activities. The Recovery Act is focused on job creation and energy savings, while the SEP is focused on energy savings. Both programs are focused on the reduction of carbon emissions that comes as a result of energy savings. Behind both programs is a fundamental premise that the adoption of more energy efficient codes is only effective if those codes are implemented and buildings are compliant with those codes. This effort offers an opportunity to:

- Understand the actual compliance rates in states, resulting in a better estimation of potential energy savings through greater compliance and better return on investments made to increase compliance
- Improve the rate of compliance through training and process improvements, thus increasing the effectiveness of more efficient codes to reduce energy use
- Understand where selected energy code criteria may need revision or enhancement to improve implementation and enforcement.

In pursuing these opportunities, the BECP has also considered the following additional goals for assisting states in these endeavors:

- Make sure compliance efforts are objective and consistently applied
- Provide guidelines that are appropriate to all states, understanding that states differ in the maturity of the code adoption and enforcement practices at the state and local level

- Consider the major logistics and manpower issues that states will be attempting to address
- Provide an opportunity to consolidate results into regional and national metrics
- Collect additional data that can be used in furthering the effort to measure and understand code compliance issues, to increase compliance rates, and to strengthen future energy codes and standards.

After evaluating both of the measurement methods against these criteria, BECP concluded that Method #2 is more supportive of these objectives than is Method #1, for reasons described below. BECP is therefore recommending Method #2 as the official metric to be used by states. However, the data collection and evaluation process being developed by the BECP will allow analysis of the evaluation data via either Method #1 or Method #2. If states would like to compare results based on both methods, it will be easy to produce compliance rates based on Method #1 as well.

5.3.1.1 Understanding the Compliance Rates in States

Oak Ridge National Laboratory (ORNL) studies that evaluated the SEP indicated that the energy savings of the Codes and Standards portion of the SEP are very impactful, rating second only to training and workshops in estimated annual energy savings (Schweitzer and Tonn 2005). In their estimates, these savings were based on an 85% compliance rate, based primarily on studies conducted in western states. Goals of this effort include gaining a more thorough and accurate understanding of the current compliance rates across the country, resulting in the ability to better evaluate the impacts of building energy codes.

BECP feels that Method #1 does not provide a metric that can be used for estimates such as the one conducted by ORNL. One state may have a single code measure that has very little impact and that is universally not complied with, but in general has buildings that perform well in comparison to equivalent code buildings. Another state may have very poor-performing buildings which fail many impactful criteria. With Method #1's pass/fail approach, these two states will receive similar, low compliance rates, yet the degree of compliance is very dissimilar. The actual energy impacts of non-compliance in these two states would be very different.

As an example, Section 403.6 of the 2009 International Energy Conservation Code (2009 IECC) contains a requirement for HVAC equipment sizing:

> **"403.6 Equipment sizing (Mandatory)**. Heating and cooling equipment shall be sized in accordance with Section M1401.3 of the International Residential Code (IRC)." (ICC 2009a)

M1401.3 of the IRC states:

> **"M1401.3 Sizing.** Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies." (ICC 2009c)

BECP believes that a large majority of residential buildings will not meet this requirement, or at least will not have demonstrated that they meet this requirement by providing calculations. If each building not meeting this requirement achieves a score of "fails", some states will receive extremely low compliance rates, even though they could have a high compliance rate with all the other provisions in their energy code. These failing buildings may be highly energy efficient, and in fact, the buildings may perform better than code even while failing this single criterion. Method #1 does little to ascertain the actual performance of the buildings in the state. If the performance of those same buildings is measured against the performance of code equivalent buildings, it is conceivable that the buildings will perform above code. In this example, the "pass/fail" metric provides very little information about the energy that is being saved or lost in the corresponding jurisdictions and states, and provides little value in estimating the impact of energy codes. While BECP believes the code requirement cited above has merit, failure based on not satisfying this single code requirement negates the energy performance of the building being evaluated, and the state metric will not provide a valuable view of potential energy savings due to non-compliance in that state.

As a second example, the IECC Section 303.1.3 requires fenestration to be rated for both U-factor and SHGC by the National Fenestration Rating Council (NFRC). This applies to site-built fenestration as well as to manufactured units. The fenestration rating process can be complicated, is lengthy (up to 100 days for a product), and requires a fee for the rating. Many jurisdictions do not require NFRC certificates for site-built windows because they are unclear on what the requirements are and how the requirements are to be integrated into the compliance process (e.g., when should the certificates be available for review by the inspectors?). While the NFRC has an established process, only a small percentage of the window manufacturers have chosen to rate their site-built products because of lack of enforcement and lack of design specifications. Unlabeled windows are assumed to have the default glazing U-factor and SHGC requirements as specified in Chapter 3 of the IECC. These are very conservative values and the windows may actually perform much better. While the requirement for labeling site-built windows also has merit, failing an entire building based on lack of certification and labeling of site-built windows can result in very low scores for buildings that may be performing well above code.

5.3.1.2 Reducing the Impact of Subjective Criteria

There are a number of code requirements that require subjective decisions on the part of the evaluator inspecting the building. For example, the 2009 IECC has prescriptive code requirements for infiltration, listing 12 generic areas that should be sealed. Section 402.4.2.2 of the 2009 IECC allows visual inspection as an alternative to an actual leakage test in verifying this code requirement. Verifying this requirement through a visual inspection of items related to "caulking and sealing" can be subjective, and it is quite possible that what a code official deemed acceptable would not be deemed acceptable by a third-party evaluator, or vice versa. It is likely even that different individuals in the same profession could disagree on acceptability. If an area of the building did not meet the criteria imposed by the evaluator, the entire building would fail to comply, regardless if it was shown to meet the air infiltration requirements based on a subsequent air leakage test of the building.

Another code requirement that could be subjectively interpreted is in Section 303.2 of the 2009 IECC:

> **"303.2 Installation.** All materials, systems and equipment shall be installed in accordance with the manufacturer's installation instructions and the International Building Code." (ICC 2009a)

There are a great many other subjective criteria that could be cited, including language such as the following: "rigid, opaque and weather resistant"; provide "sufficient" space; "durably" seal; ducts shall be "sealed"; and "restrict" infiltration. Failure of an entire building based on failure of one, subjective criterion will result in unduly low and inaccurate state compliance rates, but more importantly, it will result in metrics that provide little opportunity to understand the true impact and efficiency of the buildings being evaluated. Method #2, while not eliminating these types of subjective evaluation, greatly lessens their impact in the overall evaluation of the building and the consequent state compliance rate. If all other code requirements are met, the building can still achieve a reasonable compliance metric, rather than failing on a single criterion.

5.3.1.3 Addressing Evaluation Logistics

BECP recognizes that there are many logistical hurdles to overcome in implementing a state-wide compliance evaluation. For example, the BECP anticipates difficulties in gathering data on all code items during the appropriate stage of construction, particularly with larger commercial buildings (e.g., plan review, foundation, structural, mechanical, plumbing, electrical, and final inspection). This would require timely visits to the construction site over long periods of time, which may not always be feasible. BECP's code compliance checklists include an option to review different stages of different but similar buildings in order to provide a resulting single building compliance evaluation. This is commonly done in residential studies, where evaluators may visit a site where multiple buildings are being simultaneously constructed (e.g., housing subdivision, condominium or apartment complex, or commercial office park) with construction in varying stages occurring at the same time. The evaluators may do a foundation inspection on one building, an insulation inspection on another, and a lighting inspection on a completed building. Since the compliance percentage for a single building could also be applied to a "single building equivalent," Method #2 will more easily support this approach. Method #1 is based on the evaluation of all aspects of a single building and is less supportive of a single sampling of the building population done across multiple buildings.

5.3.1.4 Data Completeness

The complete set of data obtained from evaluations will be very important in understanding where codes are working well or failing; how they are being implemented and enforced, and where corrective actions and educational efforts are needed. BECP has concerns that evaluators asked to determine a simple pass/fail on a building will stop after the first failure is found. A complete set of data from each building is not only important in assessing compliance; it is also valuable in analyzing impacts of potential energy improvements, code barriers and weaknesses, and other measurements related to this effort.

5.3.2 Individual Building Metrics for New Construction

The materials developed by BECP include checklists of energy code requirements that can be used by evaluators to gather relevant data. In an effort to focus on the most important code requirements, the checklist items have been clustered into multiple tiers, and each tier is given a different weight in determining the overall building metric. The residential code checklist requirements are clustered into two tiers – the commercial code checklist requirements are clustered into three tiers.

A building (or multiple buildings comprising a single evaluation) which meets all of the code requirements listed on the appropriate checklist will be deemed to comply with the code and will receive a compliance rating of 100%. Failure to meet one or more items on the checklist will result in a compliance rate below 100%. The requirements in each tier will be weighted differently, with Tier 1 items receiving 3 points, Tier 2 items receiving 2 points, and Tier 3 items receiving 1 point. The building metric is determined by summing the points received, and dividing by the possible points. For example, Table 5.9 shows a building evaluated against 10 Tier 1 requirements, 5 Tier 2 requirements, and 5 Tier 3 requirements, passes 8, 4, and 5 requirements respectively. Its compliance rate would be 82%, as computed by Equation 5.6. Renovation requirements utilize a similar weighted measurement, but renovations will not receive individual building scores, as explained in Section 5.4.2.

Table 5.9. Example Building Evaluation

	Checklist Requirements	Possible Points	Requirements Passed	Points Received
Tier 1 Requirements	10	30	8	24
Tier 2 Requirements	5	10	4	8
Tier 3 Requirements	5	5	5	5

Equation 5.6

$$compliance\_percentage = \frac{points\_received}{possible\_points} \times 100 = \frac{37}{45} \times 100 = 82\%$$

5.4 Generating State Metrics

The following subsections discuss the generation of state metrics in new construction and renovations, as well as the incorporation of above-code buildings.

5.4.1 State Metrics for New Construction

The overall state metrics for residential new construction will be derived by taking a simple average of all individual building scores within the population. For new commercial construction, however, the average individual scores will be weighted by building size strata. For commercial buildings, sampling an equal number of small and large buildings will have a tendency to disproportionally represent the small building stratum, since they represent a much smaller total square footage of new construction. To account for this difference, the building compliance rates will be used to estimate the average compliance rate for each building size stratum within the state. These average compliance rates in each size stratum will then be weighted according to the proportion of total square footage constructed within each stratum (P). Equation 5.7 illustrates how the proportion weight (P) would be derived for the small building stratum – medium and large building proportion weights are calculated similarly. Equation 5.8 is used to derive the final state compliance metric.

Equation 5.7. Calculation of P for small buildings in Washington State (P_{small}).

$$P_{small} = \frac{\text{Total constructed building space for small buildings (ft}^2\text{)}}{\text{Total constructed building space for all commercial buildings (ft}^2\text{)}} = \frac{4,437,381}{34,133,700} = 0.13$$

Equation 5.8. Calculation of average state compliance score, weighted by building size.

$$P_{small} \times \left(\frac{\text{sum of building scores in small strata}}{n_{small}} \right) + P_{medium} \times \left(\frac{\text{sum of building scores in medium strata}}{n_{medium}} \right) + P_{large} \times \left(\frac{\text{sum of building scores in large strata}}{n_{large}} \right) +$$

$$P_{Xlarge} \times \left(\frac{\text{sum of building scores in X-large strata}}{n_{Xlarge}} \right) + P_{XXlarge} \times \left(\frac{\text{sum of building scores in XX-large strata}}{n_{XXlarge}} \right) = \text{Average Compliance Score}$$

where P_i = the small, medium, large, X-large, or XX-large proportion weight
n_i = the number of samples evaluated within the respective size stratum

Table 5.10 shows the inputs that are necessary to use Equation 5.8 as well as the results from Equation 5.8. These inputs are also shown in Equation 5.9, which demonstrates how the final proportion weighted mean compliance score would be calculated for our hypothetical Washington State example.

Table 5.10. Summary of inputs and results in calculating the Washington State compliance rate

	A	B	C	D = (C / B)	A x D
	Proportion of ft2 (*P*)	**Samples** (*n*)	**Sum of Building Scores**	**Average Compliance**	**Proportion Weighted Average**
Small	0.13	15	13.05	0.87	0.1131
Medium	0.17	15	12.45	0.83	0.1411
Large	0.7	14	12.6	0.9	0.63
	Total	**Total**		**Raw Mean Compliance Score %**	**Proportion Weighted Mean Compliance Score %**
Total/ Average	1.0	44		86.9%	88.42%

Equation 5.9. Calculation of the Washington State compliance rate

$$0.13 \times \left(\frac{13.05}{15} \right) + 0.17 \times \left(\frac{12.45}{15} \right) + 0.7 \times \left(\frac{12.6}{14} \right) =$$
$$0.13 \times (0.87) + 0.17 \times (0.83) + 0.7 \times (0.90) = .8842$$

5.4.2 State Metrics for Renovations

The checklists developed for new construction can also be used for evaluating renovations, where checklist items that are not applicable are marked "N/A" and will not contribute to the state metric. The variation in the number and type of code requirements being evaluated for each renovated building makes the sample size and state compliance rate more difficult to accurately estimate and determine than for new construction.

For the compliance score calculations associated with new buildings, BECP assumed that each building within the residential and commercial grouping would generally have to meet the same code requirements (e.g., the number of checklist items evaluated for each building in the sample would be comparable). This assumption does not hold for the sample of renovated buildings, which may vary greatly in the number and type of code items that must be evaluated. The scoring methodology proposed in this document assumes a primary goal of attaining a statewide compliance score for renovations as a whole for residential and for commercial buildings. It does not provide enough observations to make rigorous statistical conclusions about any sub-population within renovations.

The compliance metric for renovations will be derived by taking the total number of weighted checklist items that are evaluated for all buildings as the divisor and the number of those weighted items that are in compliance as the numerator, multiplied by 100. This calculation will not result in an individual metric being assigned to each building as was suggested for new construction, but it will provide a state-wide metric that takes into account the varied number of code requirements against which each observed renovation will be evaluated.

The checklist tiers described in Section 5.3.2 identify points for each checklist item. For example, assume that three different residential renovations were evaluated, and that the applicable checklist items came from different tiers and therefore were assigned different weights. The first renovation had 8 applicable checklists items providing a total of 24 possible points, the second had 15 items providing for a total of 35 possible points, and the third had 3 items providing for a total of 5 possible points. In this case, the sum of the possible checklist points would be 64 (24 + 35 + 5 = 64). Of the checklist items evaluated, the number of points earned for each building was 24, 28, and 4, respectively. Thus, the numerator would be 56 with a denominator of 64, which yields a proportion of 0.875 and a compliance rate for residential renovations of 87.5%.

This process is equivalent to calculating a compliance metric for each building and then calculating a weighted state compliance metric of renovations where the weights are based on the number of weighted checklist items evaluated for each building. Using the above example data, the calculation based on weights is given in Equation 5.10, where 24, 35, and 5 are the weights based on the number of weighted checklist items observed at each building and 1.0 (24/24), 0.8 (28/35), and 0.8 (4/5) are the compliance rates for each renovation. When multiplied by 100, this gives the same compliance rate as described in the previous paragraph (87.5%).

Equation 5.10

$$\frac{\frac{24}{24}\times 24+\frac{28}{35}\times 35+\frac{4}{5}\times 5}{24+35+5}=87.5\%$$

There are different methods that could be used to estimate the standard deviation associated with a renovation compliance rate from a state sample. These estimates can differ if there is a believed correlation of compliant checklist items within an observed renovation and the number of items evaluated for each renovation varies. If this correlation exists, then calculating the compliance rate for each renovation (i.e., a building compliance score) and then calculating a standard deviation between renovations in a state's sample of renovations will provide a more accurate standard deviation estimate for use in calculating an upper confidence level. This proposed method is also identical to the recommended method to estimate the standard deviation for new construction, which is also beneficial for simplicity.

5.4.3 Incorporation of Above-Code Buildings

BECP received some feedback that indicated a desire to include the impact of buildings that exceed code requirements in determining a state average. The code compliance measurement methodologies proposed in this document are for demonstrating compliance with state or local government building energy code(s). While above-code buildings and programs are encouraged, they are voluntary, market-driven programs that are not minimum law that all buildings would have to satisfy. BECP believes the goals of this effort are to understand and improve code compliance, which, where applicable, is considered a mandated baseline for new construction. If 50% of the buildings are above-code by a given amount, and 50% of the buildings are below code by that same amount, the goals of this effort would be to bring the below-code buildings into compliance. If the state compliance rate in this example was deemed to be 100%, that would indicate 100% of the buildings were compliant with the code, which is not the case. It also would imply that corrective measures were not needed, which also isn't the case.

Additionally, evaluation of the degree to which a building exceeds the code is not feasible, given the code's prescriptive nature. This could only be accomplished by simulating or measuring building performance. A performance-based evaluation of metered energy consumption of existing buildings would be a major undertaking, potentially very expensive, and it is unclear how it could be directly and readily applied to derive compliance metrics. If the codes were purely performance-based rather than prescriptive, this might be feasible. But currently there are a number of factors which could dramatically affect building energy use and are not addressed in a prescriptive code or standard, such as the climate conditions, use, occupancy schedule, and operations and maintenance activities. The results of such a study would additionally be subject to considerable discussion and debate. There is value in attempting to look at the performance of evaluated buildings, and several previous state studies have attempted to so in various ways.

6.0 Evaluation Checklists

BECP has developed checklists of energy code requirements which can be used by evaluators to gather relevant data. Checklists include instructions for their proper use and for recording the results, and graphics to assist in identifying complying and non-complying items. These may be made available as paper forms, excel spreadsheets, or online for direct input into a database and/or for use with PDAs. Paper onsite audit checklists were developed to allow automated reading into an electronic format.

This section describes the checklist contents and how they can be completed so that a compliance metric for individual new residential and commercial buildings can be developed. The checklists are also applicable for evaluating residential and commercial renovations, but as previously mentioned, are used to derive a state metric and not to score individual buildings.

6.1 Compliance Approaches

A building may comply by any of three approaches:

- Prescriptive
- Trade-off[12]
- Performance.

The checklists are generic enough to be used with any of these compliance approaches. Evaluators are instructed to review the energy code compliance documentation submitted with the plans. If documentation supporting a trade-off or performance approach is not available, the evaluation of the building is based on the prescriptive compliance path. If there is documentation supporting a trade-off or performance approach, the evaluator is instructed to evaluate the building construction based on the documentation provided with the plans and specifications for that non-prescriptive compliance approach.

For example, a building may have windows more efficient than the prescriptive requirements in the code. These windows may offset a ceiling design that does not satisfy the minimum thermal requirements of the code. If compliance documentation demonstrating this trade-off was submitted and approved, the evaluator will need to verify that the window U-factors and areas, and installed ceiling construction type and R-values match the trade-off documentation. If no documentation was submitted, the building will fail the ceiling prescriptive R-value requirement, even if it can be shown that it meets the code requirements based on a trade-off approach. While this approach might penalize buildings that *do* comply but haven't documented that compliance, it is a justified penalty in that the code requires such documentation be submitted. There are two different scenarios that could apply to this example:

- The ceiling insulation R-value(s) are marked on the plans and match those installed in the field, but no trade-off documentation is submitted. Under this scenario, the building fails one code requirement for not meeting the prescriptive ceiling R-value requirements.
- The ceiling insulation R-value(s) are not marked on any submitted plans or other documentation, nor is trade-off documentation submitted. Under this scenario, the building will fail two code

[12] The 2009 International Energy Conservation Code (IECC) contains both a U-factor alternative (Section 402.1.2) and a total UA alternative (Section 4.2.1.4). The reference to a trade-off approach in this document includes both of these alternatives, as well as the trade-off approach defined in the ANSI/ASHRAE/IESNA Standard 90.1–2007.

requirements: not identifying insulation R-values on plans and not meeting the prescriptive ceiling R-value requirements.

6.2 Using Multiple Buildings for a Single Sample

Many energy code requirements can only be inspected at specific times during the building's construction. There may be difficulties gathering data on all code requirements for a single building during the appropriate stage of construction. This would require timely and repeated visits to the construction site over a period of time, which may not always be feasible. Moreover, knowing from initial foundation inspection that a single building would be the subject of data gathering on code compliance during the entire course of construction could adversely affect the intended random nature of the compliance evaluations. The following two approaches can be used to help address these issues by evaluating different aspects of multiple buildings to generate a single sample.

6.3 Construction Phases Approach

The checklist items are grouped in sections corresponding to the phase of construction where the checklist item is typically inspected. The residential checklist requirements are grouped into the following phases. The commercial checklists are grouped similarly, with an additional inspection for electrical/lighting.

- Plan Review
- Foundation
- Framing/Rough-In
- Insulation
- Final

The checklists can be used to gather data during different stages of construction on different buildings that have the same general attributes in order to yield a resulting single composite building compliance evaluation in lieu of evaluating a single building throughout construction. This is commonly done in residential studies, where evaluators may visit a site where multiple buildings are being simultaneously constructed (e.g., housing subdivision, condominium or apartment complex, or commercial office park) with construction in varying stages occurring at the same time. The evaluators may do a foundation inspection on one building, an insulation inspection on another building, and a lighting inspection on a completed building. Where multiple buildings are used for a single evaluation, the buildings must come from the same jurisdiction and be of the same type. Where multiple commercial buildings are used for a single sample, the buildings must also fall in the same size stratum.

Much of the code compliance evaluation is performed during plan review (e.g., validation that all information needed to determine compliance is available on the approved plans and specifications). A subsequent onsite inspection ensures that what was built matches the approved plans and specifications. Where multiple buildings are used for a single sample, a plan check may be done on just one of the buildings, thus completing the plan check portion of the evaluation. For additional buildings used for a single evaluation, the plans and compliance approach should be reviewed, but not recorded in the "Plan

Review" section of the checklist. There is the possibility that one or more of the additional buildings being evaluated submitted documentation showing compliance by the trade-off or performance approach. Such a building may fail a checklist item on a prescriptive basis, but could actually comply as documented on the plans and specifications. Reviewing the plans and performance approach for each building will ensure that such a checklist item is not incorrectly marked as non-compliant.

Each checklist has general information inputs at the top of the first page which should be completed (including the conditioned floor area of the building, the compliance approach assumed by the evaluator, etc.). Some of these inputs are repeated at the beginning of each construction stage. Where a single building is being evaluated for each stage of construction, these duplicate inputs can be ignored. Where multiple buildings are used for a single evaluation, the top portion of each checklist stage must be completed for each different building evaluated.

6.4 Primary Building Approach

Where a single building can be evaluated for a large majority of, but not all of the checklist items, an alternative approach can be used. The majority of checklist items can be evaluated for the single, "primary" building, and another similar building can be used to complete the items that could not be evaluated. As an example, all of the checklist items are evaluated for a single building except for the foundation insulation, which is covered during the field visit. In this case, the checklist items pertaining to the foundation insulation can be evaluated for a different but similar building. The general information at the top of the checklist should be completed for the primary building. The general information at the top of each additional phase of construction should be left blank, since most of the checklist items were evaluated based on the primary building. The evaluator, however, should document those checklist items that were evaluated on the second building. This can be done in the comments fields corresponding to each of those checklist items.

The primary building approach could also be used for including recently occupied buildings in the sample. In this case, the code requirements that could not be evaluated because they are covered, hidden, or otherwise not available for checking in the completed building could instead be evaluated on another similar building currently under construction.

As with the construction phases approach described previously, the multiple buildings must come from the same jurisdiction and be of the same type. Where multiple commercial buildings are used, the buildings must also fall in the same size stratum. Also as described in the previous section, the plans and compliance approach of each building being evaluated should be reviewed.

6.5 Building Attributes Included

Checklists could be customized according to several criteria that impact which requirements are applicable. Different requirements may apply to different building occupancies and designs. For example, systems serving multiple dwelling units in multifamily residential buildings can have different requirements than those for single-family dwellings. Commercial buildings with vestibules have a requirement that does not apply to buildings without vestibules. Sunroom and pool heater/cover requirements are only applicable to buildings with those features. Perhaps even more relevant are the differences in code requirements pertinent to the following:

- Different commercial building uses and types have different lighting requirements
- Commercial building mechanical requirements are different depending on whether or not the mechanical systems are deemed simple or complex, as defined in Section 6.3.1 in the ANSI/ASHRAE/IESNA Standard 90.1–2007 (90.1-2007)
- Building envelope and commercial building economizer requirements vary by climate zone

An effort to create different checklists that accommodate all of these criteria would result in a large number of different checklists, which might make it difficult for evaluators to ensure they have the correct checklist for each building being evaluated. Instead, evaluators will be able to select ‘N/A’ for any checklist item that is not applicable to the building being evaluated. The same checklists will be used for new construction and renovations. For renovations, this might result in a large number of items being deemed not applicable. The main difference between complex and simple mechanical system code requirements is that complex system requirements cover a much larger number of systems. Simple system requirements are simply a subset of the complex system requirements. Therefore, for buildings with simple systems, many of the checklist items related to mechanical equipment might be marked ‘N/A.’

Different checklists were developed for each climate zone, however, and the code requirements for a given climate zone will be incorporated directly into the checklist item (e.g., a checklist item for inspecting the wall insulation R-value will include the prescriptive wall R-value for that climate zone). For lighting, the requirements for each building use is included in the checklist instructions and will be readily available to the evaluator, but the checklist item is more generic and the evaluator will have to look up the requirements for the specific building use type.

6.6 Compliance Information Collected

The building evaluations proposed in this document provide an opportunity to collect a great deal of previously unavailable data on real buildings in real world situations. As an example, very little information exists that can answer questions such as:

- What percentage of buildings comply with each of the three compliance approaches (prescriptive, trade-off, and performance)?
- Do large commercial buildings tend to have better or worse compliance than small commercial buildings?
- Do differences in building types show differences in energy code compliance rates?

The checklists were developed to collect as much information as possible without providing a great deal of additional burden on the evaluator’s time. The checklists require evaluators to note the R-values of insulation installed in the building envelope assemblies; fenestration U-factors and SHGC values; commercial building equipment efficiencies; heating and cooling equipment capacities; infiltration and duct leakage test results; commercial building lighting system controls and connected lighting loads; and generic information about the building being evaluated, such as the compliance approach and the conditioned floor area of the building.

6.6.1 Compliance Information Collected for Renovations

The checklists developed by BECP for evaluation of new construction can also be used for evaluating renovations. The number of checklist items that are applicable to a given renovation will vary, and those checklist items that are not applicable can be marked as “N/A” by the individual collecting building field data. The checklists include two inputs that are not used directly in computing the overall state compliance rate for renovations; the square footage of the renovation and the monetary valuation of the renovation. For new commercial construction, the conditioned floor area of the building being evaluated *WILL* impact the final state metric, as described in Section 5 of this document. While this input will not impact the state metric for residential new construction, nor for renovations, it is still a recommended input on the checklists as there may be value in having this information in future evaluations of data collected as part of this effort. For renovations, the checklist instructions include the following guidance on how square footage for renovations can be estimated:

- Additions: the area of the additional space being added to the building that is within the scope of the energy code
- Mechanical Systems: the area served by any new system or additions to an existing system
- Lighting Systems: the area served by the lighting retrofit(s)
- Envelope Modifications: the floor area served by and associated with the alterations.

Many data sources report the monetary valuation of a renovation. The codes themselves occasionally use this metric in determining whether or not the entire building must be brought up to all or portions of the code as if the building were new. Therefore, BECP is also recommending that this information be estimated and recorded on the checklists when evaluating renovations. This information may be available on the permit issued for the renovation.

6.7 Code Requirements Included

Not all code requirements have the same impact. In an effort to focus on the most important code requirements, the checklist items have been clustered into multiple tiers, and each tier is given a different weight in determining the overall building metric. The residential code checklist requirements are clustered into two tiers – the commercial code checklist requirements are clustered into three tiers. In both cases, Tier 1 requirements are those deemed to be ‘high-impact’ according to the following criteria:

- Items that impact design energy efficiency
- Items that impact long-term operational energy efficiency

Previously BECP considered recommending only the Tier 1 items in the checklist. Subsequent feedback has indicated that Tier 2 and Tier 3 items may often be quickly inspected, and so BECP has included all code items in the checklists except a few requirements that are deemed administrative and/or without any impact. Initial use of the checklists in anticipated pilot studies will provide additional feedback about the checklists, including a better understanding of the length of time required to evaluate a building and if any of the checklist items are particularly problematic in doing the evaluation.

6.8 Building Evaluation Time

Anticipated code compliance pilot studies may provide more accurate information about the level of effort required to evaluate residential and commercial buildings using BECP checklists. These pilots will include tracking evaluators' time spent evaluating buildings. Additional insight might be gained from a recent BCAP publication, *Residential Building Energy Codes – Enforcement & Compliance Study*, which states:

> "The average time to consider energy in a residential plan review can range from 15 to 45 minutes depending on the level of competency of the code official. The average duration of an energy residential building inspection could range from 30 minutes to 1 hour, for each visit." (BCAP 2008)

For formal compliance evaluations, the higher end of this range might be expected due to the fact that an existing, fully trained workforce may not exist for performing this additional scope of work and many of the evaluators may be newly trained. Additionally, the evaluations may not be done by jurisdictional staff in conjunction with other job duties (e.g., inspecting the insulation while already onsite to inspect structural code requirements).

The evaluations may require onsite inspection during the following stages of construction (in addition to plan review), all of which may require separate visits to the building:

- Foundation Inspection
- Framing/Rough-In Inspection
- Insulation Inspection
- Final Inspection

Plan review and four field visits, at the higher end of estimated time, could result in close to 5 hours per building. This assumes that the evaluator is located relatively close to the building site, which may not always be the case. This assumption applies to residential buildings – commercial buildings can be significantly more complex, require more visits, and therefore take longer to evaluate. Evaluation times will also vary by the size and complexity of the building being evaluated and the process used for documenting compliance. There may be opportunities to reduce these times. For example, an evaluator may visit a site where multiple buildings are being simultaneously constructed, with construction in varying stages occurring at the same time (e.g., housing subdivisions, condominium or apartment complexes, or commercial office parks). As another example, where a commercial building consists of multiple stories that are identical, inspection of some of the stories as opposed to all of the stories could be considered.

6.9 Scoring the Checklists

Just as there are several approaches for who performs the building evaluations, there are several approaches for who should compute individual building compliance percentages from the data gathered and who should consolidate these results into a state metric. Several options exist:

- The compliance determination on each building can be done by the evaluators themselves

- The completed checklists can be turned over to the state who can derive individual building and state-wide compliance percentages
- The state can enlist BECP to help electronically capture and store the checklist data, automate the scoring of each building sample, and automate the derivation of the final state metrics

BECP anticipates developing an online tool to assist in the electronic ingest and scoring of checklist data. The tool could be used by evaluators if desired. If paper checklists are used for data collection, the evaluator will need to enter the data into the online form by hand. If spreadsheet checklists are used, BECP can provide an automated method for loading the checklist information from the spreadsheet. While overall building compliance can be determined manually and documented on each checklist, one of the major values in this effort is consolidation of the data being gathered. This effort has the potential to produce the largest volume of information related to energy code compliance ever produced in this country. BECP is hopeful that regardless of the approach chosen, each state will provide its data for consolidation into a national database on energy code compliance. Assuming that the state does agree to contribute its data to such a national resource, the more effective approach is to load the data into an electronic format first, and let the computer software derive the resulting compliance scores.

7.0 References

ANSI/ASHRAE/IESNA – The American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers/Illuminating Engineering Society of North America. 2007. *Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings*.

BCAP – Building Codes Assistance Project. "Residential Building Energy Codes – Enforcement & Compliance Study." 2008. http://bcap-energy.org/files/Residential_Survey_Report_Oct08.pdf

Britt/Makela Group, Inc. 2003. "Final Report – IowaIowa Residential Energy Code Plan Review and Field Inspection Training." Iowa State Department of Natural Resources.

Britt/Makela Group, Inc. 2005. "Indiana Commercial Energy Code Baseline Study." Indiana Department of Commerce.

Britt/Makela Group, LLC. 2003. Final Report - Volume I In-Field Residential Energy Code Compliance Assessment and Training Project. Nevada State Office of Energy. http://www.energycodes.gov/implement/pdfs/nv_compliance_2003.pdf

Census Bureau – *Expenditures for Nonresidential Improvements and Repairs Statistics. Appendix A, Sample Design*. 1999. U.S. Census Bureau. http://www.census.gov/const/www/nrsupndx.html

Cochran, WG. 1977. *Sampling Techniques*, 3rd Ed. John Wiley & Sons, New York. p. 78.

Ecotope, Inc. 1998. "Baseline Commercial Construction Practices in the Pacific Northwest." 1998. http://www.energycodes.gov/implement/pdfs/Pacific_Northwest_rpt.pdf

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York. (Same text available as Gilbert, RO. 1997. John Wiley & Sons, New York.)

ICC – International Code Council. 2009a. *International Energy Conservation Code*. www.iccsafe.org.

ICC – International Code Council. 2009b. *Comparison between the 2009 ICC International Building Code (Ibc®), Ch.13 – the 2009 ICC International Energy Conservation Code (IECC®) (the Code) – and the American Society Of Heating, Refrigerating & Air-Conditioning Engineers' Standard 90.1-2007 (the Standard)*. http://www.iccsafe.org/gr/content/Documents/Stimulus%20Toolkit/Comparison-IECC-ASHRAE.pdf.

ICC – International Code Council. 2009c. *International Residential Code*. www.iccsafe.org.

Schweitzer M & BE Tonn. 2005. *An Evaluation of State Energy Program Accomplishments: 2002 Program Year*. ORNL/CON-492, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The U.S. Department of Energy's Building Energy Codes Program is an information resource on national model energy codes. We work with other government agencies, state and local jurisdictions, national code organizations, and industry to promote stronger building energy codes and help states adopt, implement, and enforce those codes.

BECP Website:
www.energycodes.gov

BECP Technical Support:
techsupport@becp.pnl.gov
www.energycodes.gov/support/helpdesk.php

EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov/informationcenter

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

PNNL-19281 • March 2010

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post-consumer waste.