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Idaho Residential Energy Code Compliance

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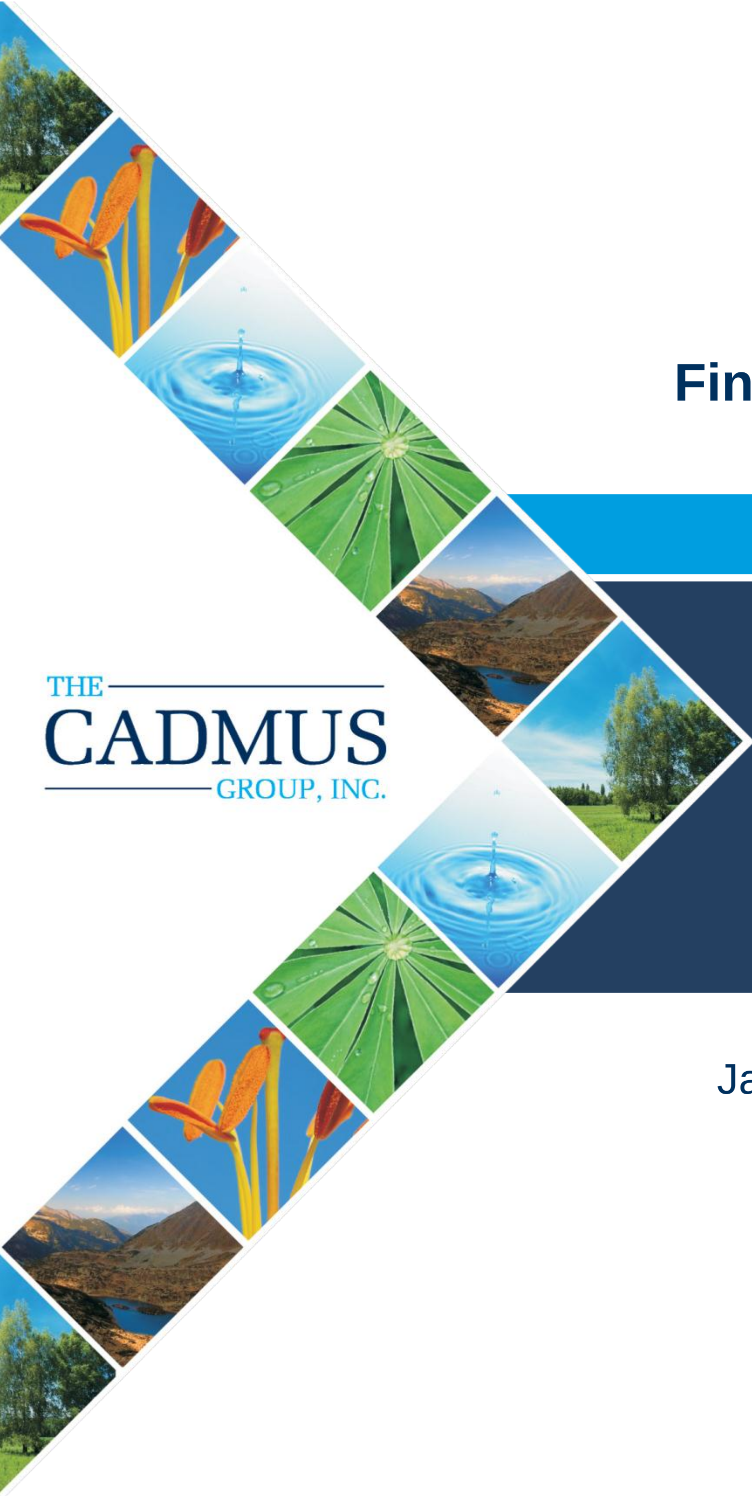

THE CADMUS GROUP, INC.

Final Report

Idaho Residential Energy Code Compliance

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1. Executive Summary

1.1. Background

The Northwest Energy Efficiency Alliance (NEEA) contracted with The Cadmus Group, Inc. (Cadmus) to conduct a study of residential energy code compliance in the state of Idaho. This effort to measure compliance has roots in the 2009 American Recovery and Reinvestment Act (ARRA), which provided funding to states, contingent upon a commitment to adopt the latest model energy codes, and to develop and implement a plan, including active training and enforcement provisions, to achieve ninety percent compliance with target codes by 2017. This commitment also included measuring current compliance each year.

This report describes the study of Idaho residential compliance with the revised state energy code—an amended version of the 2009 International Energy Conservation Code (2009 IECC).[1] Builders can choose from three approaches to demonstrate compliance: prescriptive, tradeoff, and performance. The prescriptive approach sets minimum requirements for each building component. The tradeoff approach allows the builder to tradeoff efficiencies of different components, as long as the overall component UA is at least as efficient as a building meeting all the prescriptive requirements. The performance approach requires the modeled energy use of a house to not exceed the modeled usage of the house, if built to just meet the prescriptive requirements (the reference house).

1.2. Objectives and Approach

Based on discussions with stakeholders and on NEEA's research goals, Cadmus and NEEA defined the following project objectives:

- Analyze and report current rate of energy code statewide compliance in new residential construction in Idaho, based on the Idaho version of the 2009 IECC.
- Review and comment on the various approaches for assessing code compliance.
- Determine aspects of current energy code in which enhanced code compliance would lead to the largest reductions in home energy consumption.
- Assess an approach to analyze code compliance based on the most significant items in determining energy impacts.

The compliance rate analysis in this study assesses actual compliance of homes built to the current standard. It is important to distinguish between the **compliance rate analyses** conducted for this study and the **compliance demonstration approach** used by builders to show compliance with the code for individual houses. The three methods used to analyze, or assess, code compliance in this study were developed specifically to research observed code compliance for a sample of houses and should not be confused with the compliance demonstration approaches available to builders.

[1] Idaho amended the IECC to include a prescriptive approach for log homes.

1.2.1. Data Collection

The first step in the study approach was developing a sample frame and sample of newly constructed homes. The approach was patterned after one developed by the Pacific Northwest National Laboratory (PNNL) as part of a common methodology for analyzing compliance of buildings constructed to code. The initial data came from the U.S. Census Bureau Building Permits Survey. The study used a three-stage approach to select a sample of new homes to include in site visits. The three stages were:

- County selection
- Jurisdiction selection
- Building selection

Because of the challenges expected in trying to conduct site visits and multiple visits to each home, the study team expanded the sample to sixty-six homes, instead of the forty-four generated by the PNNL methodology.

DNV KEMA conducted the site visits, and obtained building department permit information. The building characteristics were compiled in a checklist designed by PNNL for assessing code compliance based on sixty-one criteria, organized into five distinct construction/inspection stages. Additional data were collected that were needed to run building energy simulations.

1.2.2. Data Analysis

The study team analyzed compliance using three different approaches to assess the degree to which homes in Idaho complied with the new code:

1. PNNL checklist method: This approach was used to demonstrate and test the method developed by PNNL and made available for compliance analysis studies. It analyzed how well the studied homes complied with each process and efficiency requirement of the code.
2. Significant item methodology: This approach analyzed compliance based on only measures that were considered to have the most significant impact on energy use. It was evaluated as a less complex alternative to the complete checklist method.
3. SEEM energy modeling method: This method estimated energy consumption of each as-built home relative to a reference home (that is, the same home built to code). Unlike the other two methods, it provided an estimate of energy use of each home compared to its consumption if built to just meet the code.

The PNNL checklist method produces a compliance rate using site visit data analyzed based on the approach used by the builder to comply with the code. Each item on the checklist is assigned a weight used to calculate compliance points. The checklist incorporates all code requirements, including process and documentation requirements, as well as energy-efficiency requirements. In some cases, the team used available data from homes to fill gaps in the data for other homes. Compliance was calculated as the ratio of points for measures complying with the code to points possible for all observable measures.

Many PNNL checklist items have little direct effect on a home's energy consumption. To address this issue, in collaboration with NEEA, Cadmus developed an alternate, less complex methodology that encompasses only items with the most significant effect on compliance and energy use. Eight items were included in this analysis and compliance was determined as the ratio of the number complying to the total number observable. All items were weighted equally. The eight items encompassing this analysis are:

1. Window glazing U-factor,
2. Duct sealing,
3. Ducts located away from building cavities,
4. Floor insulation R-value,
5. Wall insulation R-value,
6. Ceiling insulation R-value,
7. Air sealing, and
8. High-efficiency lighting,

In the third compliance analysis approach, Cadmus used a building simulation model, SEEM94, to determine the relative energy use of as-built homes, compared to energy use of a reference prescriptive home. The analysis was based on the approach specified by the 2009 IECC Section 405, Simulated Performance Alternative. Because this compliance demonstration approach and the software do not include lighting energy use, Cadmus conducted a side calculation accounting for lighting efficiency. For each home, the compliance rate was calculated as the ratio of estimated energy use in the reference home to energy use in the as-built home.

1.3. Major Findings

Assessing code compliance through field data collection proved to be challenging because of the difficulty observing all measures covered by the code in a single visit. To fill gaps in the data collected, this study relied on building plans, data from other homes, and code default values, when necessary. The data gaps introduced uncertainty in the compliance estimates; however, when the effect of data gaps was investigated for the two code requirements for which the least data were available, the uncertainty introduced was relatively small—on the order of ten percent.

The three compliance analysis methods produced different compliance estimates as shown in Table 1. Both the checklist method and significant item method are bounded by 100 percent and provide no direct information about energy consumption. The energy modeling method has no bounds and the compliance rate calculated with this approach provides a direct indication of the energy impacts of code compliance.

Table 1. Code Compliance Levels Determined by Three Methods

Methodology	Statewide Weighted Compliance Rate
Checklist	90%
Significant Item	83%
Energy Modeling	109%

All three methods indicated relatively high compliance with the residential code in Idaho. The ARRA legislation establishes that states should strive to reach at least ninety percent compliance overall by 2017. Using the method developed by PNNL, compliance in Idaho is at that level now. The energy modeling approach indicates that compliance overall is at a level where residential energy use for space heating and cooling is less than if homes just met the code. On the average, heating energy use was nine percent less than it would be if homes just met the code. When the effect of non-compliance with the prescriptive lighting requirement is included as a sub model, overall compliance decreases and consumption is almost exactly what it would be if homes just met the code.

The compliance estimates from the checklist and significant item methods were highly correlated (at better than the 0.0001 significance level). This suggested it should be possible to estimate checklist compliance reasonably accurately by determining compliance of a subset of only the eight items used in the significant item method. However, data were difficult to obtain for several of these items, which created uncertainty in the estimates. In contrast to the checklist method, there was no statistically significant relationship between the compliance estimates from the significant item method and energy modeling approach. Consequently, it was not possible to conclude that the significant item method provided reliable information about the energy impacts of compliance.

Although the overall compliance results were positive, the team identified some areas that should receive attention.

- Wall insulation did not meet the required levels in nearly forty percent of the homes were it was observable.
- The final lighting installed in the homes was not observable very frequently, but when it was the compliance rate was only forty-two percent and the estimated effect on energy consumption was significant.
- Floor insulation compliance was low overall across the state, and especially in Climate Zone 6.
- Foundation insulation compliance was relatively low compared to other building envelope components.
- Information on infiltration and duct leakage was rarely available, suggesting that builders were not often providing it and code officials were not often enforcing this requirement.
- Compliance with the requirement to not use building cavities for air distribution supply ducts was very low.

2. Project Background

As part of its mission, the Northwest Energy Efficiency Alliance (NEEA) commits to achieving energy savings by strengthening building energy codes in the Northwest, and, as part of this commitment, has assumed a leadership role in supporting compliance with new energy codes.

To benchmark statewide compliance, NEEA contracted with The Cadmus Group, Inc. (Cadmus) and Cadmus' subcontractor, DNV KEMA, to conduct a study of residential energy code compliance in the state of Idaho. This effort to measure compliance has roots in the 2009 American Recovery and Reinvestment Act (ARRA), which provided funding to states, contingent upon a commitment to adopt the latest model energy codes, and to develop and implement a plan, including active training and enforcement provisions, to achieve at least ninety percent compliance overall with target codes by 2017.

As the governors of all fifty states pledged to meet the ninety percent compliance target, studies across the country are being conducted to examine code compliance. To support these efforts, the U.S. Department of Energy (DOE) (US DOE 2012) requested the Pacific Northwest National Laboratory (PNNL) develop a common methodology for assessing compliance (US DOE 2012). PNNL's methodology provided the basis for the approach Cadmus used in this study.

This report describes the study of Idaho residential new construction compliance with the revised state energy code—an amended version of the 2009 International Energy Conservation Code (2009 IECC).[2] In Idaho, building codes fall under the Idaho Division of Building Safety's jurisdiction by default. Local city and county governments, however, may choose to enforce state building codes, including the energy code, using their own building officials.

There are three different approaches builders can use to demonstrate compliance with the energy code: prescriptive, tradeoff, and performance. Each approach establishes specific requirements for demonstrating compliance. The prescriptive approach sets minimum requirements for each building component. The tradeoff approach allows the builder to be less efficient than the prescriptive requirements for different components, as long as other components exceed their prescriptive requirements, and the overall component UA[3] is at least as efficient as a building meeting all the prescriptive requirements. The performance approach requires the modeled energy use of a house as designed to not exceed the modeled usage of the house if built to just meet the prescriptive requirements (the reference house).

Two other factors affect these approaches. First, for the prescriptive and tradeoff approaches, the home must have at least fifty percent high-efficacy lighting.[4] No such requirement exists for the performance approach so less efficient lighting could be installed under this approach. Second, when using the performance approach, the amount of glazing in the reference house must equal

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[2] Idaho amended the IECC to include a prescriptive standard for log homes.

[3] UA is measure of the amount of heat that would be transferred through a given surface or enclosure (such as a building envelope) with a one degree Fahrenheit temperature difference between the two sides. The UA is calculated by multiplying the U-Value by the area of the surface (or surfaces).

[4] Idaho 2009 IECC defines high-efficacy lighting as follows: 15 watts or less minimum of 40 lumens per watt; 15-40 watts, minimum of 50 lumens per watt; over 40 watts, minimum of 60 lumens per watt.

the amount in the house as-built, unless the ratio of glazing area to floor area exceeds fifteen percent. For ratios above fifteen percent, the reference house has a glazing-to-floor area ratio set to fifteen percent. Neither the prescriptive nor tradeoff approaches establish any requirement for glazing area. This requirement means under the performance approach builders have to increase the efficiency of other measures in homes with large amounts of glazing.

In addition to requirements directly related to energy efficiency, the code establishes requirements intended to document information related to compliance. For example, a compliance certificate must be posted and insulation must be installed according to manufacturers' directions, regardless of the approach followed.

To ensure the study is representative of current statewide building patterns, Cadmus and NEEA conducted a half-day meeting on Tuesday May 8, 2012, with Idaho stakeholders. The meeting allowed these stakeholders to learn the study's purpose and steps, and to provide input on the methodology used to analyze compliance. The meeting produced a key result: the group determined construction data compiled by the U.S. Census Bureau was the best available for sampling, and, if sampled, local jurisdictions could provide permit numbers for recent construction.

Stakeholders participating in the meeting and in sampled jurisdictions proved very helpful in the project's success. Cadmus greatly appreciates the assistance of all these parties throughout the conduct of this study.

2.1. Study Objectives

Based on discussions in the stakeholder meeting and on NEEA's research goals, Cadmus and NEEA defined the following project objectives:

- Analyze and report current rate of energy code statewide compliance in new residential construction in Idaho, based on the Idaho version of the 2009 IECC.
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3. Sample Development and Selection

This chapter describes Cadmus' process for developing the project's site-visit sample.

3.1. Data Sources for New Construction Activity

In developing the sample of new residential construction in Idaho, the process began by utilizing U.S. Census Bureau (U.S. Census Bureau 2012) Building Permits Survey (U.S. Census Bureau 2012) data for 2009, 2010, and 2011. PNNL used the same data source, and project stakeholders agreed these data best represented construction activity in the state, and provided the best available data source for statewide sampling.

Though PNNL used the same data source to develop its sample generator (US DOE 2012) for code compliance studies, the PNNL calculator only used data for 2008 through 2010, as 2011 data were unavailable at that time. Use of 2009 through 2011 construction data maintained use of a three-year average to minimize bias resulting from unusually high or low construction years in specific counties, but improved the sample's representation of construction activity since implementation of the current code.

However, gaps exist in the Census data. The Bureau fills these gaps by: using data obtained through the Survey of Construction (U.S. Census Bureau 2012); or by estimating activity levels, using the previous periods' level and the ratio of current month authorizations to the prior annual total for reporting locations. The Bureau's Website (U.S. Census Bureau 2012) provides more information on compilation of permit data.[5]

3.1.1. Estimating Idaho's Residential Construction Population

Table 2 shows the IECC climate zone, and the number of construction starts for all forty-four Idaho counties. Cadmus calculated the three-year average annual starts shown, and the percentage of statewide activity.

3.2. Staged Sample Selection

This study used the basic sampling methodology PNNL developed for code compliance studies described in *Measuring State Energy Code Compliance* (US DOE 2010). The method suggests sampling forty-four homes, the minimum number required to test ninety percent compliance with a one-sided ninety-five percent confidence interval (and the variance of 169 assumed by PNNL). Drawing upon experience conducting previous compliance studies, the study team knew limited data could be collected from single visits to homes, and the study scope did not permit multiple visits to each home. Thus, in consultation with NEEA, the study expanded the site-visit sample to sixty-six to provide sufficient data to address the study's research objectives.

The sampling procedure required three stages to select individual buildings for analysis:

1. County selection
2. Jurisdiction selection
3. Building selection

[5] To check the reasonableness of compiled data, the study compared reported permits in the Census Bureau data to data compiled by the City of Ammon, Idaho. The City of Ammon collects similar data from across the state, which proved to be the next best available data source for this study. With one exception, construction activity across the reported locations proved very comparable, with similar changes in construction activity over time. A significant discrepancy between the two data sets emerged for Nez Perce County, where the City of Ammon report showed twice as much construction activity as the Census data. This discrepancy's impact is described in section 3.2.2 of this report. The comparison reassured the research team that using Census Bureau data for sampling was appropriate for the study.

The following sections describe each of these stages.

Table 2. Idaho Construction Activity by County, 2009–2011

FIPS Code	County Name	IECC Climate Zone	2009	2010	2011	Average Annual Starts	Average Percent of Statewide Activity
1	Ada	5	1,341	1,277	1,344	1,321	35.19
3	Adams	6	13	13	7	11	0.29
5	Bannock	6	152	138	75	122	3.25
7	Bear lake	6	20	27	27	25	0.67
9	Benewah	5	24	19	9	17	0.45
11	Bingham	6	84	58	56	66	1.76
13	Blaine	6	27	24	30	27	0.72
15	Boise	6	38	24	28	30	0.80
17	Bonner	6	3	17	9	10	0.27
19	Bonneville	6	236	254	218	236	6.29
21	Boundary	6	47	29	26	34	0.91
23	Butte	6	8	1	4	4	0.11
25	Camas	6	1	4	6	4	0.11
27	Canyon	5	387	312	223	307	8.18
29	Caribou	6	17	7	8	11	0.29
31	Cassia	5	33	37	33	34	0.91
33	Clark	6	11	2	2	5	0.13
35	Clearwater	5	27	20	20	22	0.59
37	Custer	6	11	9	3	8	0.21
39	Elmore	5	95	37	15	49	1.31
41	Franklin	6	57	52	34	48	1.28
43	Fremont	6	61	52	31	48	1.28
45	Gem	5	19	13	14	15	0.40
47	Gooding	5	25	12	9	15	0.40
49	Idaho	5	3	4	2	3	0.08
51	Jefferson	6	83	65	49	66	1.76
53	Jerome	5	60	54	47	54	1.44
55	Kootenai	5	776	498	431	568	15.13
57	Latah	5	65	65	65	65	1.73
59	Lemhi	6	12	20	21	18	0.48
61	Lewis	5	10	0	2	4	0.11
63	Lincoln	5	16	3	2	7	0.19
65	Madison	6	94	52	29	58	1.55
67	Minidoka	5	9	36	50	32	0.85
69	Nez Perce	5	44	46	47	46	1.23
71	Oneida	6	14	19	10	14	0.37
73	Owyhee	5	20	11	12	14	0.37
75	Payette	5	32	38	32	34	0.91
77	Power	5	9	9	7	8	0.21
79	Shoshone	5	4	2	7	4	0.11
81	Teton	6	39	16	11	22	0.59
83	Twin falls	5	261	198	159	206	5.49
85	Valley	6	47	46	23	39	1.04
87	Washington	5	27	23	19	23	0.61

3.2.1. Stage 1: Selecting Counties

The first stage randomly allocated sixty-six sampling points to counties within the state, using a probability proportional to size methodology. This resulted in selection of fifteen unique counties, with four counties representing the smallest amount of construction activity removed and their sample points redistributed to any county with only one sample point originally allocated. The redistribution controlled research costs, while minimally impacting final study results, given the limited construction activity represented by the affected counties.

3.2.2. Stage 2: Selecting Jurisdictions

The second stage determined jurisdictions sampled within each county. Before sampling, the study team created a basic rule-set to determine the number of jurisdictions visited in one county, based on sample points allocated to that county. The methodology also equally distributed sample points within each county across the selected jurisdictions. These rules controlled data collection costs. Table 3 shows the basic rule-set created to establish the number of jurisdictions selected within a county, based on the number of homes (sample points) required.

Table 3. Jurisdiction Sampling Rules

Number of Sample Points	Number of Jurisdictions
1–5	1
6–10	2
11–15	3
16–30	4

Table 4 shows the fifteen original counties and eleven final counties selected for the study. The table includes the number of jurisdictions sampled within each county.[6] As shown, selected counties represented about eighty-one percent of estimated housing starts (after removing the four counties with the least construction), targeting sixteen jurisdictions for sampling.

Of the four sample points originally allocated to each of the four removed counties, three were reallocated equally to Jefferson, Jerome, and Nez Perce counties. As previously noted in section 3.1, there was a significant discrepancy between the number of building starts reported in the Census Bureau data and the City of Ammon's construction reports for Nez Perce county. Due to this discrepancy, the study reallocated the remaining sample point to Nez Perce county to avoid potentially under-sampling the county in case a high building activity level appeared at the jurisdiction level.

3.2.3. Stage 3: Selecting Specific Homes

In selecting specific homes from within a jurisdiction, the study first gathered all new permit data supporting new residential construction. A contract established with Mr. George Klomp, a recently retired building official in Idaho facilitated collection of the necessary permit data in each selected jurisdiction. Mr. Klomp contacted each jurisdiction, and requested provision of permit data to the research team.

Upon receiving permit data for each home being built in the jurisdiction, the study team could create a randomly ordered list of homes for site visits. For each jurisdiction, the list included a greater number of sites than the number of sites needed for visitation. Cadmus provided the list to the DNV KEMA team for site visit scheduling.

[6] Jurisdictions sampled and their individual results remain confidential.

Table 4. Stage 1 and 2 Sampling

County	IECC CZ	Percent of Statewide Construction	Original Sample Size	Final Sample Size	Jurisdictions Sampled
Ada	5	35.2	27	27	4
Kootenai	5	15.1	14	14	3
Bonneville	6	6.3	5	5	1
Canyon	5	8.2	4	4	1
Twin falls	5	5.5	3	3	1
Bannock	6	3.2	2	2	1
Bingham	6	1.8	2	2	1
Fremont	6	1.3	2	2	1
Jefferson	6	1.8	1	2	1
Jerome	5	1.4	1	2	1
Nez Perce	5	1.2	1	3	1
Boise	6	0.8	1	Removed	
Owyhee	5	0.4	1	Removed	
Caribou	6	0.3	1	Removed	
Butte	6	0.1	1	Removed	
Total		83	66	66	16

4. Data Collection

After completing the sample design procedure, Cadmus provided the DNV KEMA field data collection team a roster of ongoing construction projects to use for potential site visits.

4.1. Site Visit Process

The site visit team worked down the list of selected homes to schedule site inspections. In some cases, the team deviated from the original list when unable to perform site visits to homes selected in the sample, due to the following reasons:

- Occupants in a fully constructed home would not permit a site visit.
- The builder could not be reached.
- The home had been in a fire.

Developing a substitution procedure addressed these circumstances. In order of preference, the study adopted the following process, selecting:

1. Another home farther down the provided list.
2. A home located near the one that could not be recruited.
3. A home by the same builder.
4. A home selected at random by driving around the jurisdiction.

Overall, it was necessary in only about one-fourth of the cases for the DNV KEMA team to use this approach to make substitutions.[7]

4.2. Data Collection Forms

4.2.1. PNNL Form

PNNL provides a series of checklists[8] for analyzing compliance of residential new construction with the 2009 IECC (US DOE 2010). Checklists used for this study began with PNNL's checklist, for a combined Climate Zone 4 and 5 Marine, and for Climate Zone 6, with both tailored to Idaho code requirements.

A complete assessment, using the PNNL checklist, required inspecting homes and construction documents to determine compliance with sixty-one criteria, organized into five distinct construction stages:

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

For each item, compliance reviewers recorded one of the following entries: Yes (complies), No (does not comply), N/A (item does not apply to a given house, such as skylights), Not Observable (item applies but cannot be verified, often because it could not be observed during the visit).

4.2.2. SEEM Model Input Form

To conduct an energy-usage compliance analysis, Cadmus selected an energy simulation tool—Simple Energy Enthalpy Model (SEEM) Version 94—to model participating homes in this study. To provide inputs required for the SEEM runs, the study added thirty additional data fields to the PNNL form, including:

- Building type
- Foundation details
- Conditioned floor area

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[7] The field team made every effort to maintain the sample's randomness, such as avoiding clusters of homes due to their ready accessibility.
[8] See Appendix C for a sample PNNL checklist.

- Wall area
- Fenestration areas and orientation
- Ceiling type

4.2.3. Data Entry Methodology

Cadmus entered collected data into a SQL server database management system, using a Web-based tool. For each home in the sample, field staff entered as much information as possible into the database. Field visits collected two types of data:

- Plans-verified data: Building blueprints, Construction documents, REScheck documents, Builder information provided verbally (in the absence of written sources)
- Field-verified data: All energy-efficiency characteristics observable during site visits

In some cases, plan data could be obtained on site during home site visits. In other cases, DNV KEMA obtained plans information through visits to building departments.

The study marked data points not verified visually during home site visits as “Not Observable” (N/O), and data points not relevant to the home as “Not Applicable” (N/A).

4.3. Compliance Determination

The study team used the modified PNNL checklist to determine compliance for each home visited. The checklist provided flexibility in analyzing compliance, based on one of the three compliance demonstration approaches selected by builders. The three approaches are:

- Prescriptive
- Tradeoff
- Performance

When collecting compliance information and analyzing the data, Cadmus applied the checklist in accordance with how the builder chose to demonstrate compliance and guidance provided by PNNL on how to apply the checklist (see section 5.1).

This included a hierarchy of the data used for the study:

1. When observed, field-verified values were always used to assess compliance.
2. When field-verified values were not observed, the study used plan-verified values obtained from one of the sources listed above.
3. Only for the energy modeling methodology was a value required if neither a field-verified nor plan-verified value was observed. In this case, the prescriptive code value was assumed.

In cases where field-verified data were not available, checklist compliance assessment could be done by either treating the item as unobservable or using the plans-verified data. The research team elected to use the plans-verified data to improve the accuracy of the results as illustrated in Table 5. The table shows the case where four equally weighted items are in a checklist section. The first row shows the actual compliance rate for that section based on half the items complying and half not. The second row shows the value calculated by treating the fourth item as unobservable. The last row shows the average effect of using the plans-verified value, assuming the plans are correct only half the time. The calculated compliance of 0.375 is closer to the actual value, 0.5, than if the item is excluded from the calculation entirely. . Since we may assume the plans are correct more than half the time, the accuracy of the calculated compliance rate will likely be much closer to the actual value.

Table 5. Effect of Plans-Verified Data on Compliance Estimate

Approach	Item 1	Item 2	Item 3	Item 4	Compliance Rate
Actual	No	Yes	No	Yes	50%
Treat as Not Observable	No	Yes	No	N/O	33%
Use Plans	No	Yes	No	50% Yes/50% No	37.5%

4.3.1. Prescriptive Approach

For thirty homes—just fewer than one-half of the homes visited by the study team—the builder followed the prescriptive approach to demonstrate compliance, which specifies minimum requirements each building component must meet, with no tradeoffs permitted. The approach presents requirements in terms of R-values or U-values by envelope component, requires a minimum of fifty percent high-efficacy lighting, and does not place limits on amounts of glazing that can be installed.

Evaluating homes complying by the prescriptive approach using the checklist proved relatively straightforward. The field team visited the home, and filled in information for each item on the compliance checklist. Given that the team did not make multiple visits to each home, all required measures were not always observable during site visits. In such cases, the team gathered plans information on site, if available. Other cases required visits to local code jurisdiction offices to review permit files and to verify planned values for compliance items.

4.3.2. Tradeoff Approach

For thirty-six homes—just over one-half of those visited by the study team—the builder demonstrated compliance through the tradeoff approach. This approach allows homes to comply even if certain building envelope items do not meet prescriptive requirements, as long as each respective home achieves an overall UA value less than or equal to that achieved if each building envelope component only met the prescriptive approach requirements. The same lighting efficacy specified in the prescriptive approach applies. Builders choosing to comply using this method generally utilize the REScheck software, provided by DOE (US DOE 2010).

When using the checklist to evaluate a home following the tradeoff approach, DNV KEMA's field staff obtained REScheck materials from local permit-issuing offices, then, when completing the site visit checklist, compared field-verified values of checklist items against REScheck values rather than against prescriptive requirements.

4.3.3. Performance Approach

For three homes visited by the study team, builders used the performance approach to demonstrate compliance. This approach determines compliance at the whole-house level using a simulation model. When using the checklist to assess compliance for a home following this approach, compliance was determined by comparing as-built construction characteristics to values used in the simulation model.

4.4. Description of Data

DNV KEMA collected data from sixty-nine homes, as listed in Table 6. The number of homes visited exceeded the predetermined sample size for two counties.[9]

Table 6. Distribution of Homes in Sample and Completed Site Visits, Local Code Jurisdictions

County	Sampling Plan Site Visits	Completed Site Visits
Ada	27	29
Bannock	2	2
Bingham	2	2
Bonneville	5	5
Canyon	4	4
Fremont	2	2
Jefferson	2	2
Jerome	2	2
Kootenai	14	14
Nez Perce	3	2
Twin Falls	3	5
Total	66	69

Table 7 shows the distribution of homes by the approach builders used to demonstrate compliance in the selected counties. The majority of these sixty-nine homes used the tradeoff approach or the prescriptive approach: fifty-two percent of homes visited chose the tradeoff approach; forty-three percent chose the prescriptive approach; and four percent chose the performance approach. Ada County had the largest number of homes using the tradeoff approach, with three times as many homes using that approach rather than the prescriptive approach. Only three homes used the performance approach.

As anticipated, DNV KEMA faced difficulties in collecting all checklist data for each home visited. Due to the different construction stages of each home during inspections, not every data point could be gathered through field verification, or even from plans. Further, some construction

[9] One county, Nez Perce, had a final sample size one less than its sample size target (three homes). Though DNV KEMA inspected three homes in that county, when Cadmus reviewed the submitted data, it appeared one inspected home was a remodel and not new construction. As the project focused on compliance in new homes, Cadmus removed the home from analysis.

documents required as part of the checklist, could not be obtained from building departments. Consequently, all homes visited included some entries recorded as "Not Observable." Table 8 shows the overall distribution of checklist compliance items. Nearly one-half of items did not apply. Of those applicable checklist items, compliance or non-compliance could be determined for about forty-four percent.[10]

Table 7. Distribution of Site Visits by County Area and Compliance Demonstration Approach

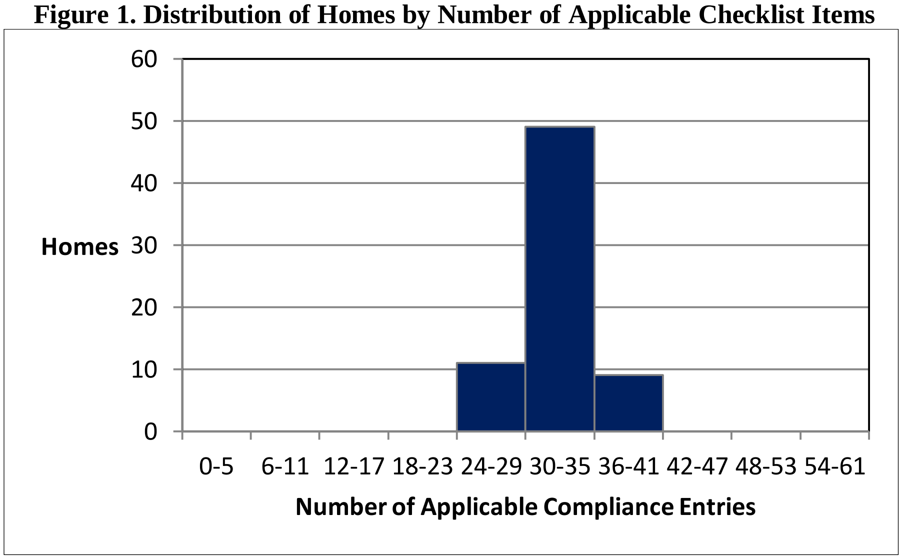
County	Prescriptive Approach	Tradeoff Approach	Performance Approach	Total
Ada	7	21	1	29
Bannock	1	1	0	2
Bingham	1	1	0	2
Bonneville	0	3	2	5
Canyon	0	4	0	4
Fremont	2	0	0	2
Jefferson	2	0	0	2
Jerome	2	0	0	2
Kootenai	8	6	0	14
Nez Perce	2	0	0	2
Twin Falls	5	0	0	5
Total	30	36	3	69

Table 8. Average Distribution of Compliance Entries

Compliance Entry	Statewide
Yes	19.6%
No	3.6%
Not Observable (N/O)	29.2%
Not Applicable (N/A)	47.6%

Figure 1 shows distributions of homes, based on the number of applicable PNNL checklist items. For most homes, about one-half of items on the list applied.

Figure 1. Distribution of Homes by Number of Applicable Checklist Items



[10] Using the data in the table this is calculated as [(19.6%+3.6%)/(19.6%+3.6%+29.2%)].

Figure 2 shows the distribution of homes—based on how many compliance items could be observed and verified—both complying or not complying. Nearly forty homes fell within the range of twelve to seventeen observable items. In no home were 30 or more items observed.

Figure 2. Distribution of Homes by Number of Observed Checklist Items

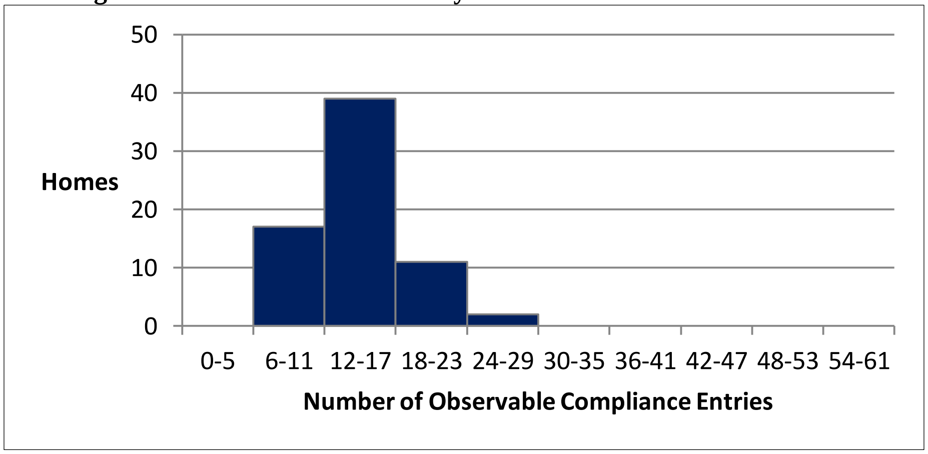
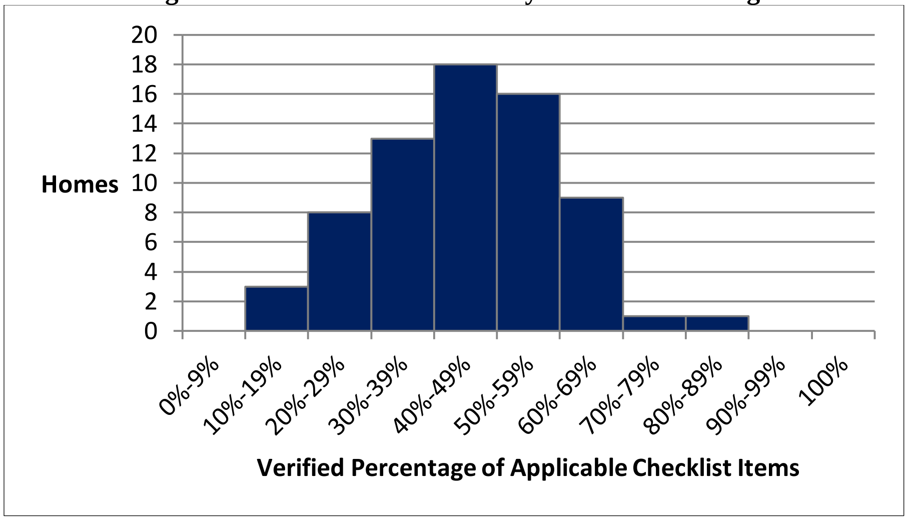


Figure 3 shows distributions of the percentage of observed checklist items, out of the total applicable. About one-half of homes fell within forty percent to fifty-nine percent of items observed. For eleven of the sixty-nine homes, fewer than thirty percent of the items were observed. More than seventy percent of applicable measures were observed in only two homes. Observing measures proved most difficult during the insulation inspection stage, given the typically short time between insulation and drywall installations (the latter covering the insulation).

Figure 3. Distribution of Homes by Verified Percentage



4.5. Data Collection Challenges

The study team obtained permit information from local building departments. Several obstacles, however, were encountered in obtaining permit data:

- Though seeking officially public information, convincing building officials to provide permitting information proved very difficult. However, the sixteen departments contacted eventually agreed to provide some information.
- As most building departments did not maintain permit information electronically, in-person visits were required to request or examine permit data.
- When contacted, two jurisdictions reported not yet adopting the 2009 code. As the project sought to assess statewide compliance with the 2009 IECC, in consultation with NEEA, the study team obtained permit data for these homes and included them in the sample.

4.5.1. Supplementing Incomplete Checklist Data

An ideal, complete evaluation following the PNNL protocol requires visiting a home several times to analyze compliance at different construction stages. In practice, few compliance studies, to date, have had the available resources to conduct the number of site visits implied by this approach; this includes the present study. Expanding the sample size to sixty-six homes helped address this issue by collecting data on more homes from various construction stages that could be combined to fill gaps in the information available for individual homes.

For each home, the study calculated the percentage of verified compliance items for each checklist section. Although PNNL recommends making multiple visits to the same home to collect compliance data at each construction stage, the PNNL method allows for data to be combined from different buildings: "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."[11] Since the scope for this project did not permit multiple visits, the study team used this alternate approach to fill in data gaps for the homes visited.

The study team recognized that, when checklist items were not observable, the accuracy of the checklist compliance rate was reduced because no information was included for the unobservable items. The team judged that the alternate approach could be used to apply available data from some homes to fill data gaps of other homes in the same jurisdiction as a way to minimize the effects of unobservable items on accuracy. To do so, the team made the decision that data from homes where more than half the items in a checklist category were observed could be applied to those homes where less than half the items were observed. The selection of one-half as the threshold was somewhat arbitrary, but took advantage of more complete information and minimized the effect of unobservable items on accuracy. The study team applied the following rules in line with PNNL's methodology (see section 6.1.2) in deciding how to fill data gaps:

- Supplemental data could *not* be used for homes in jurisdictions where only one or two homes were sampled.

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[11] Please see page 6.2 of PNNL's *Measuring State Energy Code Compliance* document.

- Supplemental data could *not* be used if only one home where the percent of verified checklist items for a given checklist section was greater than or equal to fifty was present in a given jurisdiction

- Supplemental data values (for example, the attic R-value) for a home were determined by taking the average of checklist section data from all homes in the same jurisdiction with sufficient data for that section.

Supplemental data were used to replace data only for a given section of the checklist. For example: If a home was considered a candidate for supplemental data for the foundation insulation section, supplemental data were used to replace all checklist items of the section. In other words, supplemental data replaced verified items in addition to missing items of the candidate home's foundation insulation section.

Table 9 shows distributions of homes that were candidates for use of replacement data by checklist section. Generally, the number of homes where less than one-half of items were verified increased for later checklist sections. The table also shows how many homes could be adjusted using values from homes with more data available. The most homes adjusted occurred in the Framing/Rough-In stage (sixteen of sixty-nine, or twenty-three percent).

Table 9. Distribution of Candidate and Adjusted Homes by Checklist Section

Checklist Section	Total Homes	Candidate Homes (< 50% Verified)	Adjusted Homes
Pre-Inspection	69	7	2
Foundation	69	35	11
Framing/Rough-In	69	39	16
Insulation	69	47	12
Final	69	55	9

4.5.2. Supplementing Incomplete Modeling Data

Energy modeling required collecting basic building characteristics data (such as insulation R-values), but did not require the paperwork or some supplementary data required in the PNNL checklist. For modeling energy consumption, the study could observe most data points needed as model inputs. Figure 4 shows, across the entire sample, direct observations in the field collected fifty-eight percent of data points. Another twelve percent derived from plans and construction documents, or from information provided by builders.[12] The remaining thirty percent of data points could not be obtained using either the field-verified or plans-verified data.

Information visually collected through field-verified observations varied by home, depending on the home's construction stage. Home characteristics and components with data most often available included: home size, windows, and mechanical systems. As shown in Figure 5, overall infiltration rates and duct system leakage often could not be verified from plans or data gathered in the field.

[12] Only three cases required obtaining information from builders.

The energy model used in this study requires every parameter to have an associated value. This required developing an approach to deal with parameters when values could not be obtained through inspections or documentation reviews. This differed from the checklist approach, where data missing due to unobservable components did not factor into the compliance determination.

Figure 4. Information Sources for Modeling

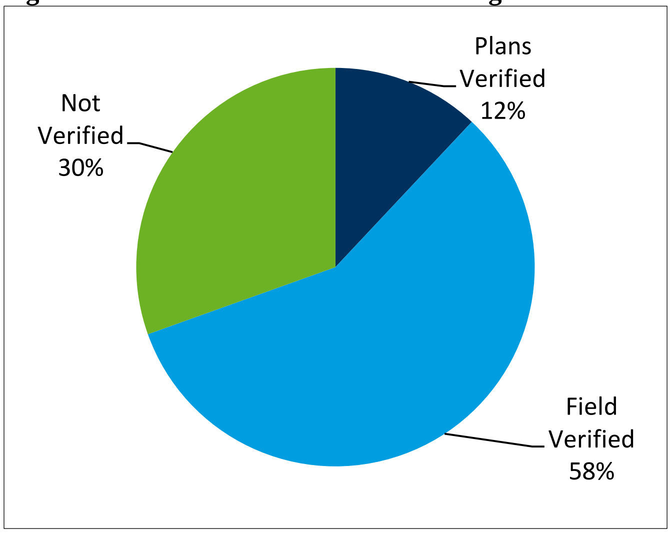
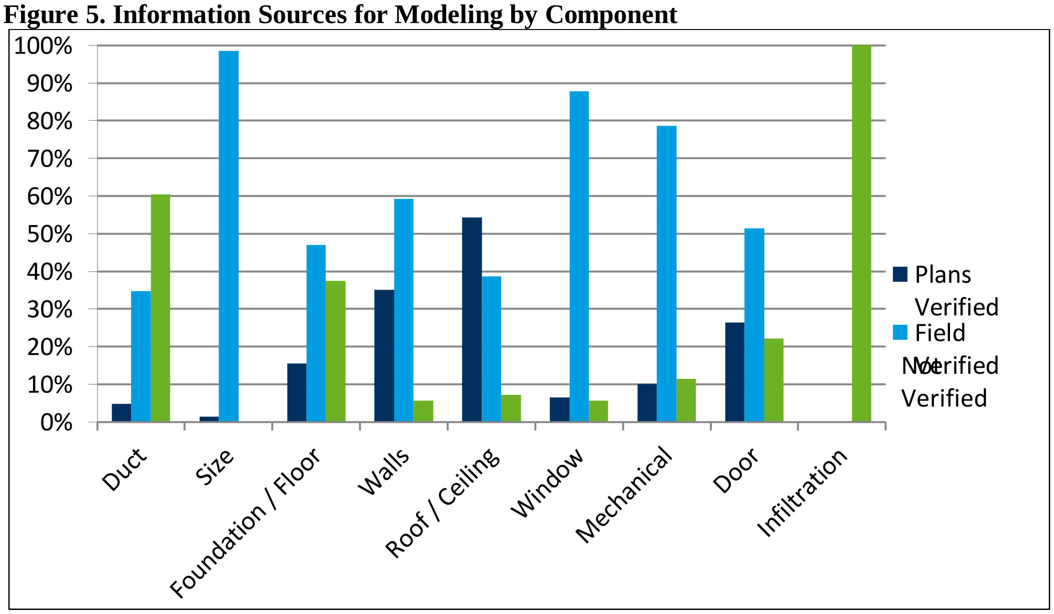


Figure 5. Information Sources for Modeling by Component



Note: "Not Verified" indicates the information was not available from the plans or field visits.

For each parameter value that could not verified (e.g., floor insulation level, slab insulation) the following hierarchical steps were applied to fill in the missing value:[13]

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[13] The regional Residential Building Stock Assessment (RBSA) presented another possible source of current building practice, but only about six new Idaho homes in the RBSA sample had been built during the relevant period, thus this sample size could not provide adequate accurate data for this study.

1. For parameters with other data available from similar homes in the jurisdiction, the mean of those available values could be calculated and used for the unknown data.
2. For parameters without data available from similar homes in the jurisdiction, code minimum values could be used.

In the first case, the study assumed similarities in construction and code enforcement practices in individual jurisdictions. The PNNL method allows data to be combined from different homes in a development, and the approach extended this basic practice to a broader area, expecting sufficient commonality in practices to prevent significantly biased results. In cases where similar data could not be obtained, the study assumed the specific building component just met the prescriptive code requirement, a method chosen because: (1) no basis existed for choosing a different value; and (2) using this value had no net effect on energy use, compared to the reference building modeled for comparison (as described below).

There were two cases where neither approach to fill in missing data was possible: for infiltration and duct system air leakage. This was because those values had to be based on test data, not observable parameters. As testing depended on home size, those values could not be extrapolated to other homes in the sample.[14] For modeling purposes, the study assumed all homes had natural infiltration rates, just meeting the value required upon performing a blower door test.[15]

For ducts in unconditioned spaces, code requires leak testing with a duct blaster, and specifies conducting the test at 25 pascals pressure. During our data collection, duct blaster results could be obtained for only a few homes, with many tests at 50 pascals.[16] The study adopted the simplifying assumption that all homes with ducts in unconditioned space just met code requirements for the following reasons:

1. Duct leakage test results could be obtained for a limited number of homes.
2. Most tests were conducted at the higher pressure.
3. SEEM requires a different leakage metric as an input.[17]

The study set duct leakage to zero in the SEEM model runs for homes with all ducts in conditioned spaces since there would be no duct leakage outside the envelope.

As described later, the study team assessed the sensitivity of the results to making these default assumptions.

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[14] Code allows builders to provide blower door test results or have envelopes inspected for potential leakage sources. Visual inspections were used by builders to demonstrate compliance in all cases, except for ENERGY STAR homes. Field visits compiled blower door data for the small number of ENERGY STAR homes. However, a review of these data found reported values not credible or possibly recorded incorrectly. Consequently, the study did not incorporate these data in the simulation analyses.

[15] The code states compliance can be achieved: "…when tested air leakage is less than seven air changes per hour (ACH) when tested with a blower door at a pressure of 50 pascals (1 psf)."

[16] A contractor in Idaho indicated ENERGY STAR required conducting duct tests at fifty pascals.

[17] The review of the few duct blaster results indicated they met code requirements.

5. Analysis Methodologies

5.1. PNNL Checklist Methodology

The PNNL method develops a compliance rate for each home using the checklist and site visit data. This rate evaluates each home, based on the approach used by the builder to comply with the code: prescriptive, tradeoff, or performance.

The checklist methodology assigns each of the sixty-one items on the checklist a value of one, two, or three points, depending on PNNL's assessment of the relative importance of each. Summing points across all sixty-one items resulted in 159 possible points. Detailed data are presented in Appendix A.

Using this method, building-level compliance could be determined by dividing the total points for all items marked as compliant by total points associated with all items marked compliant or non-compliant, with results expressed as a percent. The compliance analysis excluded items marked "Not Applicable" or "Not Observable." For a home considered compliant with this method, the resulting percentage must equal one-hundred percent.

$$\frac{\sum Compliant\ Measure\ Points}{\sum Compliant\ Measure\ Points + \sum Non{-}compliant\ Measure\ Points} = Compliance\ Rate\ \%$$

5.1.1. Application to Prescriptive Approach

In using the checklist method to evaluate homes complying by the prescriptive approach, verified values are compared against prescriptive code values, which can be found on PNNL's checklist. The verified values were from the field collection team when available. When field-verified values were not observed but plan-verified values were observed, the plan-verified value was used to compare against the prescriptive code value.

5.1.2. Application to Tradeoff and Performance Approaches

The checklist method can also be used with homes adopting the tradeoff or performance approach. For a home complying using the tradeoff approach, values specified in the provided worksheet or software report could be used to assess compliance. For a performance approach, values specified in the performance software analysis could be used to assess compliance.

The values in the worksheet or software report for the tradeoff approach or in the performance software analysis are known as plan-verified values. To assess compliance, field-verified values are compared against plans-verified values. As long as field-verified values meet or exceed plan-verified values, the respective checklist item is deemed compliant. When a field-verified value does not meet a plan-verified value, the respective checklist item is *not* compliant. For a given checklist item, if a plan-verified value is observed and a field-verified value is not observed, the item is deemed compliant as long as documentation of the tradeoff or performance approach exists and is verified. For a given checklist item, if a field-verified value is observed and a plan-verified value is not observed, the field-verified value is compared against the prescriptive code value.

When a builder used a tradeoff or performance approach to comply with code, but valid outputs or reports proved unavailable to indicate the building features specified to meet the code, PNNL recommends evaluating homes using the checklist prescriptive approach.

5.1.3. Supplementing Missing Data

In cases of missing data, PNNL suggests combining data from multiple buildings to derive a single building evaluation. This could occur during simultaneous construction of multiple buildings, with construction of different buildings at different stages. PNNL recommends using the same building for at least one complete inspection stage (e.g., plan review, foundation, framing, insulation, or final inspection). Additionally, buildings must be of the same type and be located in the same jurisdiction.

During data collection and analysis, this study combined data from multiple buildings, as needed, to create a composite building. When combining data, this study relied on data for homes in the same jurisdiction, preferably by the same builder and in the same development.

5.1.4. Determining Statewide Compliance

For analyzing statewide compliance, PNNL discusses two possibilities[18]:

1. Determine the percentage of compliant homes.
2. Take a simple average of the house-level compliance rates.

PNNL prefers the second method, as it provides a better indication of how buildings comply overall. Cadmus agrees, but finds both metrics informative, and, hence, reports both.

5.2. Significant Item Methodology

In the PNNL methodology, each of the sixty-one compliance items receives a weight value ranging from one to three points. Cadmus finds this small range insufficient to capture the relative effects of checklist measures on energy consumption (the ultimate impact of code compliance). Many checklist items affect a home's energy consumption little. Some (such as posting a certificate describing energy features on the home's electricity panel) may be important from a procedural perspective, but do not directly contribute to energy usage. To address this issue, Cadmus developed an alternate methodology in conjunction with NEEA, encompassing only items with the most significant effect on compliance and energy use.

This alternative method removed the influence of less-important compliance items by restricting analysis to the eight checklist items deemed most significant in determining energy consumption. The items were selected by the study team in conjunction with NEEA, and the method was employed in a prior study of code compliance in Montana for NEEA (Lee, A., Cook, R., Horton, D. 2012). This method allowed the analysis to consider whether builders complied with the most vital components of the 2009 IECC affecting energy use, regardless of whether builders complied with other requirements of lesser importance. The eight items in this analysis included:

[18] Please see section 5.4 of PNNL's *Measuring State Energy Code Compliance* report.

1. Window glazing U-factor
2. Duct sealing
3. Ducts located away from building cavities
4. Floor insulation R-value
5. Wall insulation R-value
6. Ceiling insulation R-value
7. Air sealing
8. High-efficiency lighting

Other than this change, Cadmus applied the remainder of the PNNL method as designed. Each of the eight items above received a three-point weight in the PNNL checklist, equally weighting them in this alternate analysis. As with the PNNL method, the compliance rate calculated for each home reflected the percentage of items deemed code-compliant, averaging these to estimate a statewide compliance level. (Analysis excluded items rated “Not Applicable” or “Not Observable” as the PNNL methodology excluded these.)

5.3. SEEM Energy Modeling Methodology

5.3.1. Energy Consumption Methodology

Cadmus used SEEM94 to determine the relative energy use of sampled homes, compared to energy use of the same homes if they were constructed to exactly meet the code. Ecotope developed SEEM94 for the Northwest Power and Conservation Council and NEEA, primarily to model heating and cooling energy consumption and savings for utility planning purposes. Cadmus adopted the model as it can be applied in other residential energy use studies in the Northwest. SEEM94 offers all the capabilities necessary for this study and is not overly complex. This helped minimize input errors and inconsistent results.

Energy use simulated for the reference house could be compared to the simulated energy use of the sampled as-built home. The procedure used prescriptively-compliant reference homes for all models to be sure those homes in the sample were compared on a consistent basis. Builders’ compliance demonstration approaches proved unimportant as the study sought to compare energy consumption of each home as-built to a minimally-compliant home. If builders used an approach allowing tradeoffs between prescriptive requirements, the simulation model accounted for these in its energy consumption estimate.

Notably, not all energy code aspects could be modeled, so the analysis did not account for these in the energy estimates. For example, the modeling analysis did not include lighting, swimming pool equipment, and sunrooms. Although these home end uses contribute to energy consumption, code does not specify their requirements (except lighting, in the prescriptive compliance demonstration approach) or the model did not have the capability to analyze them. Overall, however, the simulation analysis was very consistent with the code’s scope.

5.3.2. Defining As-Built Homes

Cadmus modeled each home, based on its observed, as-built characteristics, and compared it to a code-compliant reference home. In all cases, the study used minimally compliant prescriptive requirements to define the reference home.

As addressed, incomplete data collection results could not be ignored in modeling. This required: combining site visit data and data from plans; cleaning data; and filling remaining gaps. The resulting specifications constituted the as-built home design entered into the model. The SEEM model energy-use estimate based on these inputs provided the estimate of energy consumption of each as-built home.

5.3.3. Defining Reference Homes

Reference homes were modeled using, the same size, orientation, window area, wall area, roof area, and foundation type as the corresponding as-built homes. In defining the reference home, the code requirements were used to specify insulation values and U-values. Table 402.1.3 in the 2009 IECC gives prescriptive requirements by component, and Table 405.5.2 gives the IECC's modeling parameters for simulated performance. Table 10 shows component U-value specifications used, by climate zone.

Table 10. Reference Home U-Values

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Crawlspace Wall U-Factor
5	0.35	0.60	0.030	0.057	0.060	0.033	0.059	0.065
6	0.35	0.60	0.026	0.057	0.057	0.033	0.050	0.065

In addition to these prescriptive envelope requirements, the code establishes requirements for duct leakage, ducts in unconditioned space, and whole house tightness. Cadmus used code prescriptive requirements for these measures to determine corresponding inputs for SEEM runs.

A significant difference occurs between the simulated performance approach, described in Section 405 of the 2009 IECC, and the prescriptive approach. Modeling specifications described in Table 405.5.2 include a requirement to use the same ratio of window area to conditioned floor area in the reference home as in the as-built home, up to fifteen percent. Above fifteen percent, the reference home is set at fifteen percent, regardless of the as-built percent.

On the other hand, neither the prescriptive nor tradeoff approach uses requirements related to window area. In effect, capping the window area in the reference home forces builders using the performance approach to increase the overall efficiency of the thermal envelope if the home has a large window area.

A single method for selecting the reference home glazing area (rather than varying it depending on the compliance method used by the builder) simplified the modeling analysis. As only three homes complied using the performance approach, the prescriptive method of setting the reference home window-to-floor area ratio equal to the ratio for the as-built home proved appropriate. Thus, modeling used all requirements of 2009 IECC's simulated performance alternative, except for window-to-floor area specifications.[19]

Dividing energy usage of the reference home by energy usage of the as-built home provided a measure of each home's compliance. For consistency with the terminology used throughout this report, this ratio is referred to as the compliance rate. In this case, the compliance rate can be above 100 percent for homes that use less energy than the reference home. A home using more energy than a code-compliant home received a compliance rate less than 100 percent. To be consistent with the IECC method, energy usage was calculated in Btus, using a source energy multiplier of 3.16 source Btus per site Btu for electricity and 1.1 for all other fuel sources.[20] This resulted in a compliance rate calculated as follows:

$$\frac{Energy\ Usage\ Reference\ Home}{Energy\ Usage\ As\ Built\ Home} = Compliance\ Rate\ \%$$

6. Checklist and Significant Item Analyses Results

In this chapter, Cadmus presents statewide compliance rate results generated from the PNNL checklist and significant item compliance analyses. Chapter 0 presents the compliance results using the simulation analysis.

For all three approaches, the study team developed a weighting scheme to address the fact that building codes vary across climate zones. The analysis treated climate zones as a stratification variable. Within each climate zone, the analysis treated counties as level-one sampling units, and individual building starts within counties as level-two sampling units. The resulting weight, calculated as follows, applied to each project-level compliance rate:

$$w_{j,k}^{\text{region}} = \frac{M_i}{\sum_{\substack{\text{sampled } j \\ \text{in zone } i}} N_j} \cdot \frac{N_j}{n_j} \text{ (Here, } i \text{ is the climate zone containing county } j.\text{)}$$

Appendix B: Derivation of Weights presents details of the weighting approach.

6.1. PNNL Checklist Compliance Results

6.1.1. Component-Level Results

To gain insights into compliance at the component level, Cadmus summarized compliance information for each measure on the checklist, determining the frequency that each component could be verified (that is, it was applicable and observable) and the compliance rate. Table 11 presents results for each compliance item category, including: the number of items on the

[19] This assumption made the window requirement a little less stringent for the three homes where the builder complied using the performance approach.

[20] The 2009 IECC specified these factors as an average for the U.S.; for the Pacific Northwest, the factors would differ somewhat. These factors are used here to be consistent with the IECC methodology. For purposes of calculating energy impacts later, the study reports site energy.

checklist contributing to the category's compliance level, the percent verified, and the compliance percentage adjusted as described in Section 4.5.1. Table 21 in Appendix A: Line Item Compliance provides more detailed information.

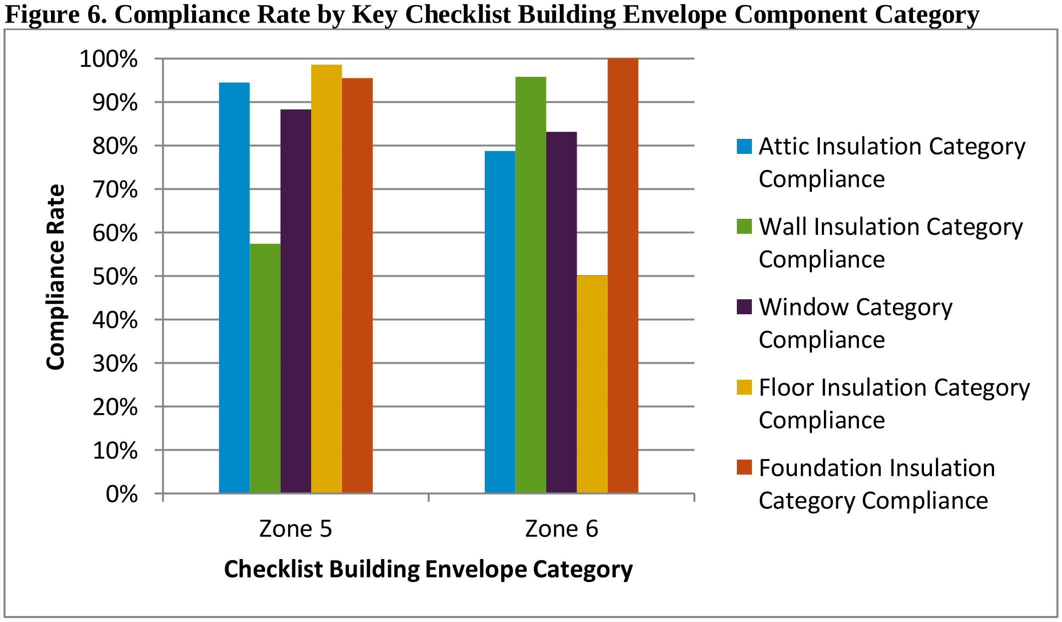
Table 11. Summary Component Checklist Compliance Statistics

Compliance Item Category	Number of Items	Percent Verified	Adjusted Average Compliance
Pre-Inspection	2	62%	89%
Foundation	12	42%	96%
Framing/Rough-In	18	39%	93%
Insulation	13	35%	74%
Final	16	29%	81%

As the table shows, the percent of items that could be verified (that is, were observable) decreased in the later inspection stages. In the final stage, data for the seven typical items were commonly collected on ceiling insulation levels, but rarely for infiltration or duct leakage.

Figure 6 graphically displays information on checklist compliance rates by different building component category and climate zone. Each component category represents multiple code requirements in the checklist. For example, the window category includes: window U-value, window SHGC, window labeling, and other code requirements.

Figure 6. Compliance Rate by Key Checklist Building Envelope Component Category



This produces results notable for two reasons. First, unlike many of other results, they differ significantly between climate zones. For example, the wall insulation category shows a compliance rate greater than ninety percent in Climate Zone 6, but just less than sixty percent in Climate Zone 5.

Second, these compliance rates are not necessarily good indicators of their effect on energy consumption. As will be seen in Figure 6, floor insulation in Climate Zone 5 is less efficient on a relative basis than other building components, but the results shown in Figure 6 indicate this checklist category offers the highest compliance rate in Climate Zone 5. These differences resulted from the checklist combining disparate factors, including some without direct effects on energy use, in determining compliance rates for a category. The results in Figure 6 are interesting in the context of the PNNL checklist, but do not reliably indicate energy effects of compliance variations in different building components because of the inclusion of items in each category that do not affect energy use.

Homes complying through the prescriptive approach also had to meet a requirement that at least fifty percent of lighting was high-efficacy. Even though many of the sampled homes were observed late in the construction process, the installed lighting could be determined for only twenty-seven percent of homes in the sample due to lighting not installed at the time of the visit. For those homes where lighting was installed at the time of the site visit, only forty-two percent met the requirement, a compliance rate lower than any of the categories displayed in Figure 6.

6.1.2. Adjustments for Missing Data

Table 9 shows the number of sampled homes where data from other homes were used to fill data gaps. Table 12 summarizes the effects by checklist section. In all cases, using values from other houses with more complete data increased or did not change the estimated compliance rate at the checklist section level and, for most checklist sections, the change was relatively small. Overall, filling the gaps where possible increased the average checklist compliance rate from eighty-six percent to eighty-seven percent without any weighting applied.

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Table 12. Compliance Rate Effect of Filling Data Gaps, Unweighted

Checklist Section	Unadjusted Average Compliance	Adjusted Average Compliance
Pre-Inspection	88%	89%
Foundation	90%	96%
Framing/Rough-In	91%	93%
Insulation	73%	74%
Final	81%	81%
Total	86%	87%

6.1.3. Checklist Compliance of Homes Complying under Tradeoff and Performance Approaches

Checklist compliance for the thirty-six homes for which builders used the tradeoff approach to demonstrate compliance and the three homes where they used the performance approach was determined by using the plan-verified values as the basis for assessing the field-verified values. For homes complying by the tradeoff approach, the plan-verified values were from the REScheck run; for homes complying by the performance approach, the plan-verified values were those used in the simulation analysis. When only a plan-verified value was available, the corresponding item was deemed compliant based on the same rationale described in section 4.3. Table 13 shows the checklist compliance rate for homes complying by each of the three code compliance approaches. The table indicates the homes complying by the prescriptive approach scored slightly lower than homes complying by either the tradeoff or performance approach. Based on the precision with a ninety percent confidence level, builders using the tradeoff approach have a statistically significant higher compliance rate than builders using the prescriptive approach, but the performance compliance rate is not different from the other two rates at a statistically significant level.

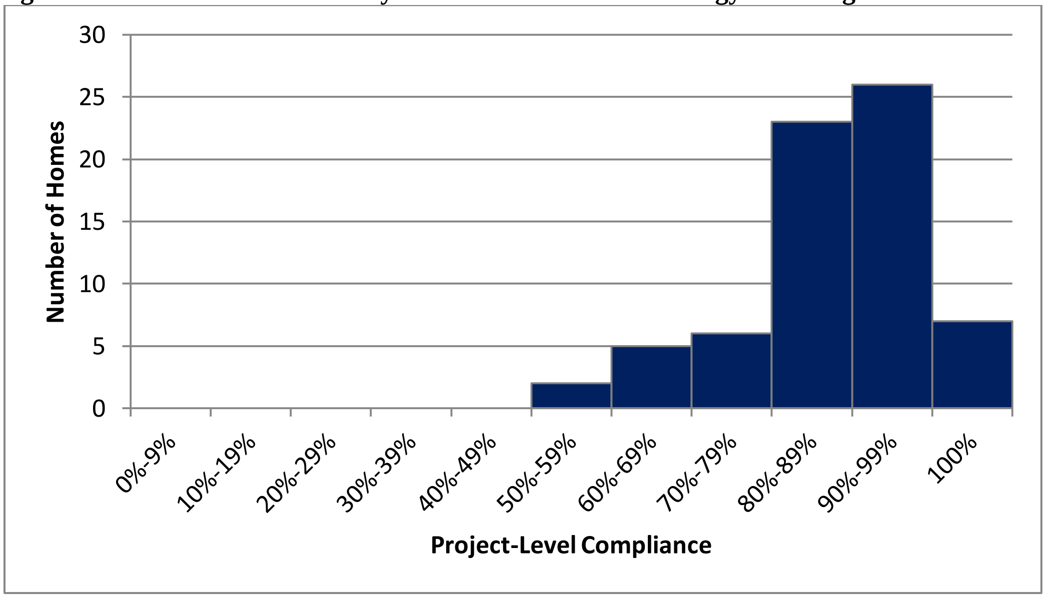
Table 13. Checklist Compliance Rate by Builder Compliance Demonstration Approach and Precision at 90% (Unweighted)

Builder Compliance Approach	Average Checklist Compliance	90% Confidence Level Precision
Prescriptive	82%	5%
Tradeoff	91%	3%
Performance	88%	9%
Total	87%	3%

6.1.4. Aggregate Results

With the data gaps filled as described in Section 6.1.2, the adjusted data resulted in one home having the lowest compliance rate of fifty-four percent with the PNNL checklist analysis method. The highest rate was one-hundred percent, and the mean was eighty-seven percent. Figure 7 shows distributions of adjusted project-level compliance rates without geographic weighting. Only seven homes fully complied under the PNNL checklist method. Full compliance only means code requirements verified either through plans or field observation complied; those not observed, naturally, could not be assessed.

Figure 7. Distribution of Homes by PNNL Checklist Methodology—Unweighted



Analysis of statewide compliance estimates produced the following results:

- The percentage of homes achieving one-hundred percent compliance.
- Average home-level compliance rates:
  - Without weights applied
  - With climate zone weights applied (as discussed in Appendix B: Derivation of Weights)

Table 14 presents these statewide results. Overall, after adjusting for missing data, only ten percent of homes fully complied with the code requirements using the checklist. However, a weighted, average compliance rate of ninety percent resulted across the state.

Table 14. Summary of PNNL Checklist Results for Statewide Compliance

Scenario	Unadjusted Statewide Result	Adjusted Statewide Result
Percentage of homes achieving 100% compliance (unweighted)	13%	10%
Average compliance rate (unweighted)	86%	87%
Average compliance rate (weighted)	88%	90%

6.2. Significant Item Results

Using the Significant Item analysis method resulted in twenty-nine homes of the sixty-nine having a compliance rate of one-hundred percent, and the mean compliance rate was eighty-three percent. Figure 8 shows distributions of project-level significant item compliance rates without climate zone weighting.

Figure 8. Distribution of Houses by Significant Item Checklist Methodology—Unweighted

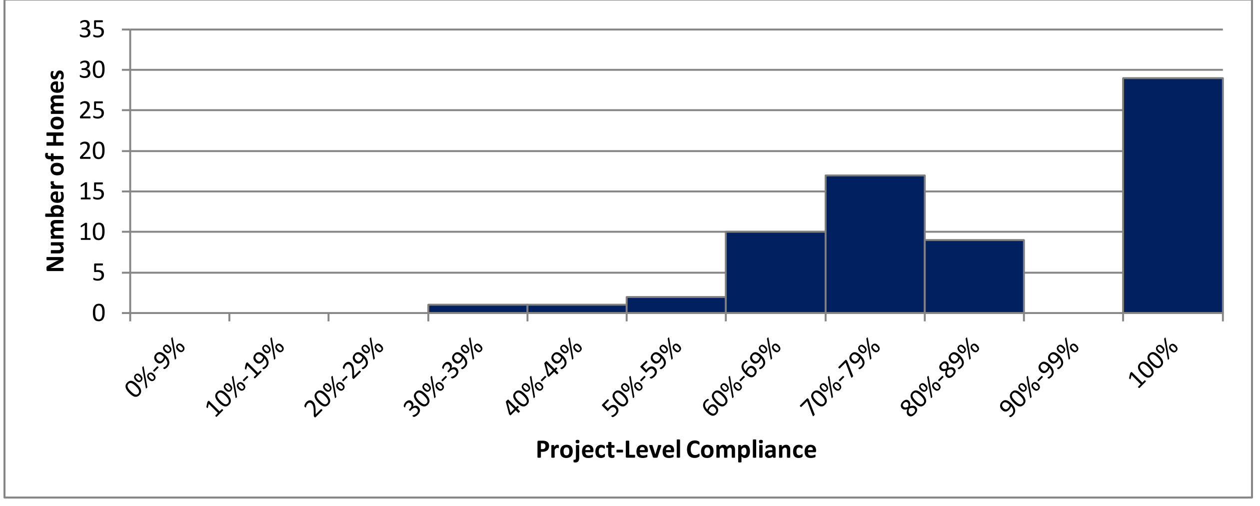


Table 15 presents the statewide results using the significant item approach. Overall, forty-two percent of homes fully complied with the code requirements using the significant item method. A weighted average compliance rate of eighty-three percent resulted across the state.

Table 15. Summary of Significant Item Results for Statewide Compliance

Scenario	Statewide Result
Percentage of homes achieving 100% compliance (unweighted)	42%
Average compliance rates (unweighted)	83%
Average compliance rates (weighted)	83%

Compared to the PNNL checklist results (Table 14), the significant item approach results in a substantially larger share of homes rated one-hundred percent compliant. Twenty-nine homes fully comply using this method compared to only seven using the full checklist method. This is not surprising given the smaller number of items considered in this method. However, thirty-one homes have a compliance rate less than eighty percent compared to only thirteen with the checklist method, resulting in an average compliance rate less than with the checklist method.

Table 16 summarizes compliance of the eight significant items. Compliance for not using building cavities for supply ducts is very low (but is based on only twenty homes where observation was possible). Similarly, air sealing compliance is low, based on only five homes.

Table 16. Summary of Significant Item Results for Statewide Compliance (Unweighted)

Item	Number of Verified Homes	Statewide Compliance
Glazing U-value	64	100%
Ceiling insulation R-value	65	95%
Duct sealing	20	95%
Floor insulation R-value	36	94%
Wall insulation R-value	65	62%
Lighting efficacy	19	42%
Air sealing	5	40%
Building cavities not used for supply ducts	8	25%
Overall	69	83%

7. SEEM Modeling Results

This chapter presents results of the compliance assessment conducted in this study using the modeling methodology.

7.1. Space Heating and Cooling Results

Of sixty-nine homes modeled, SEEM modeling results for space heating and cooling produced compliance rates ranging from ninety-nine percent to 141 percent, with a mean of 110 percent. As shown in Figure 9, very little variation occurred in the compliance rate, though energy usage varied by nearly a factor of ten from the smallest to largest energy use, with a sample standard deviation of only six percent.

Weighting results to extrapolate to the average for the population of new homes in Idaho resulted in a 109 percent compliance rate, or just slightly less than the unweighted average. This shows statewide energy use of new homes is about 8.3 percent less than if all new homes just met the code.

The overall effect of compliance on energy consumption depends on the magnitude of each component's effect on energy use. Figure 10 displays the UA for each component, and the difference can be observed between the average value for the reference and as-built homes. Differences in UA-values are directly related to energy consumption differences. The largest reduction in UA occurred for walls. Consequently, walls contributed the most to as-built homes consuming less energy than reference homes.

Figure 9. Compliance Rate vs. Energy Consumption, Space Heating and Cooling

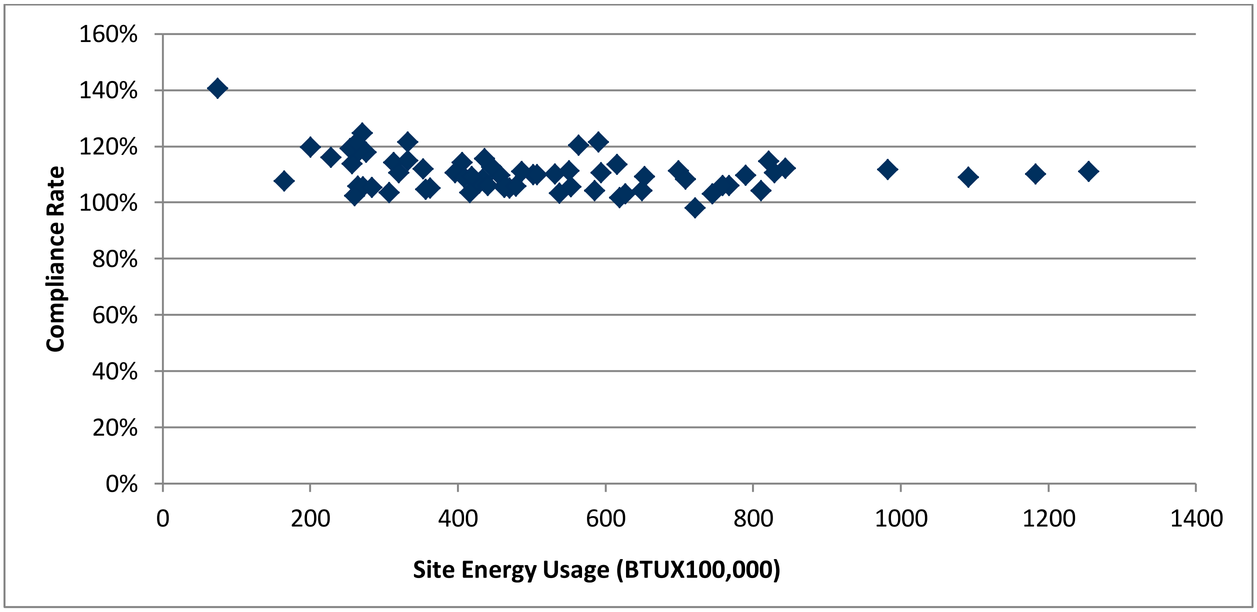
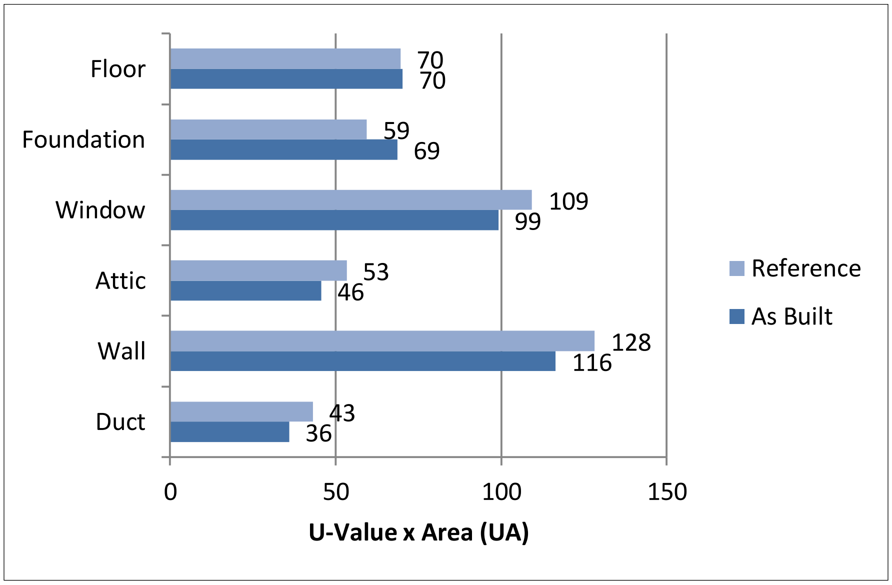


Figure 10. Component UA Difference between As-Built and Reference Homes

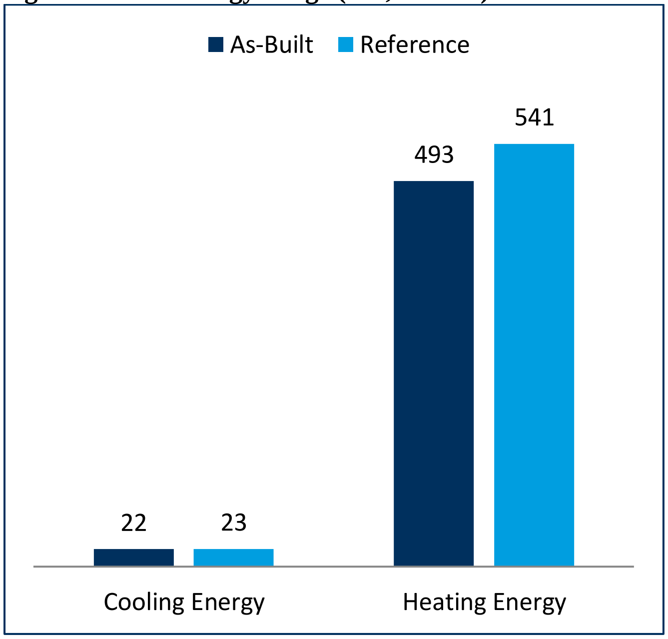


The second largest contribution resulted from windows more efficient than required by code. Attic insulation contributed the third-largest amount to overall improved energy performance. The as-built foundation and floor UA exceeded the value for the reference home and, thus, negatively affected compliance, though not enough to offset the more efficient values for other components. For buildings as a whole, the as-built homes exhibited an average UA-value 6.3 percent better than the average reference home value.

Energy modeling indicated energy consumption of as-built homes is less than minimally code-compliant new homes, primarily because of reduced space heating energy use. As shown in

Figure 11 new homes in Idaho saved, on average, about 4.8 million Btu (48 therms) per year in site energy for heating compared to homes just meeting code. Cooling energy consumption impacts proved less significant, due to internal loads (lighting, occupants, and appliances), serving as major drivers of the annual cooling load, unaffected by envelope efficiency.

Figure 11. Site Energy Usage (100,000 Btu)



7.2. Lighting Compliance Effects on Energy Consumption

The code's performance compliance demonstration approach did not require lighting to be included in the energy modeling. As a result, when the study team used the simulated energy consumption analysis, the results did not account for compliance levels for the prescriptive approach's lighting efficacy requirements. To understand the impact of lighting on energy consumption, the study team separately estimated lighting energy consumption for both non-compliant and compliant homes. Section 404.1 of the IECC 2009 energy code adopted by Idaho reads:

> Lighting equipment (prescriptive). A minimum of 50 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps.

The annual lighting kBtu was estimated using data from the 2012 Residential Building Stock Assessment (RBSA), and from the Regional Technical Forum (RTF) (see Appendix D). For high-efficacy lamps, Cadmus assumed compliant homes installed fifty percent CFLs, and non-compliant homes installed only incandescent lighting; this is the most conservative assumption. Table 17 shows the annual average modeled home space heating and cooling consumption, kBtu lighting energy consumption, and verified compliance rate based on the unweighted results.

Table 17. Modeling Results with Lighting Energy, Unweighted

Model	Space Heating & Cooling Consumption (kBtu)	Lighting Non-Compliant Annual (kBtu)	Lighting Compliant Annual (kBtu)	Lighting Compliance Rate	Total Energy with Lighting (kBtu)
Average Reference Home	72,130	29,912	18,574	100%	90,704
Average As-Built Home	65,827	29,912	18,574	42%	90,977
		Compliance Rate Including Lighting			99.7%
		Compliance Rate Excluding Lighting			110.0%

The reference home is assumed to be 100 percent compliant with the lighting requirements, or fifty percent of the lighting is high-efficacy. For the homes visited, Cadmus found forty-two percent to be compliant. It should be noted the study team was able to verify lighting compliance in only twenty-eight percent of the homes inspected because lighting was not often fully installed at the time of the site visit.

As the table shows, the lighting impact on annual energy consumption is very significant. Adding lighting energy use to the space heating and cooling energy consumption increases estimated energy consumption of as-built homes forty-five percent (29,912/65,827) in the non-compliant case and twenty-eight percent (18,574/65,827) in the compliant case. The calculated unweighted average compliance rate drops from 110 percent when lighting is not included to 99.7 percent when lighting is included. This finding illustrates the importance of the current lighting energy code in the prescriptive requirements.

7.3. Effects of Assumed Data Points on Modeled Results

Because assumptions had to be made in the modeling analysis when field-verified data were not available, the study team investigated the uncertainty introduced in the results by these assumptions. Since data from blower door and duct leakage testing were the least available and both duct leakage and infiltration have large impacts on energy consumption, this study examined impacts of the assumptions used to fill gaps in these values. When data were missing, the modeling analysis assumed that both infiltration and duct leakage just met the code requirements.

The best data available for comparison purposes derived from the 2012 RBSA (Ecotope. 2012), a study characterizing residential building energy use and the current building stock across the Northwest. The current study modeled the sixty-nine sampled homes using SEEM with the default assumption of just meeting code, and then applying the upper and lower bounds from the RBSA data, and comparing the results. The effects are shown in Table 18.

The variation in the RBSA infiltration data provides an error band around this study's estimated space heating and cooling compliance rate of about plus or minus ten percent. This is a relatively small uncertainty and, since it is approximately equal on either side of the average value estimated in the study, it does not provide any evidence the study value would be increased or decreased by incorporating measured infiltration. The best available data for infiltration and duct leakage shows that these assumed values are reasonable.

Table 18. Compliance Rate Variability

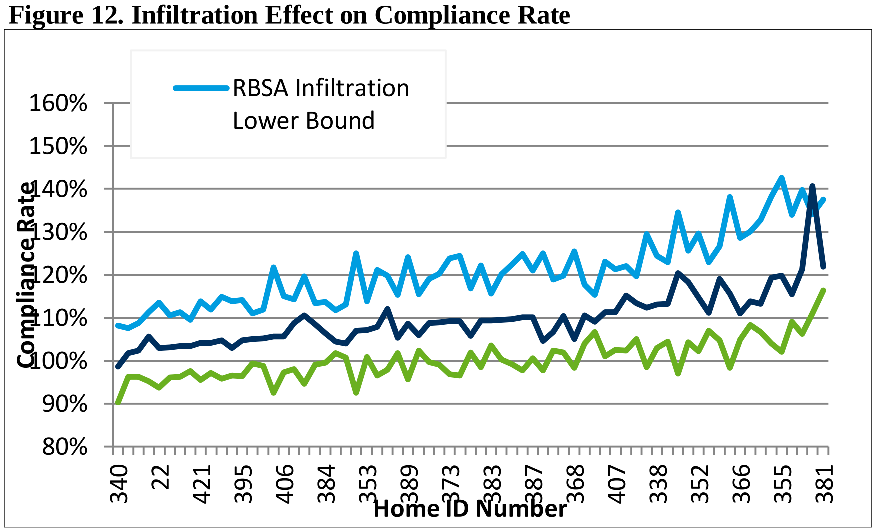
Input	Assumption	RBSA 2012 Mean	Upper Error Bound Of RBSA Data	Lower Error Bound Of RBSA Data	Upper Bound Effect On Compliance Rate	Lower Bound Effect On Compliance Rate
Infiltration	0.00036 SLA* (Approx. 7ACH50)	6.33 ACH50***	8.09 ACH50	4.57 ACH50	-9%	11%
Duct Leakage	88% Thermally Efficient**	27.2% Duct Leakage****	34.8% Duct Leakage	19.6% Duct Leakage	-9%	-4%

**SLA (Specific Leakage Area)
**Assuming 12% duct leakage as modeled input.
***Mean of 20 homes built between 2006-2010 across MT, ID, WA, and OR.
**** Mean of 24 homes in Idaho all vintages.

Figure 12 presents the effects of the upper and lower bounds on the compliance rates for each home analyzed. In all but one case, the study value is within the error band.

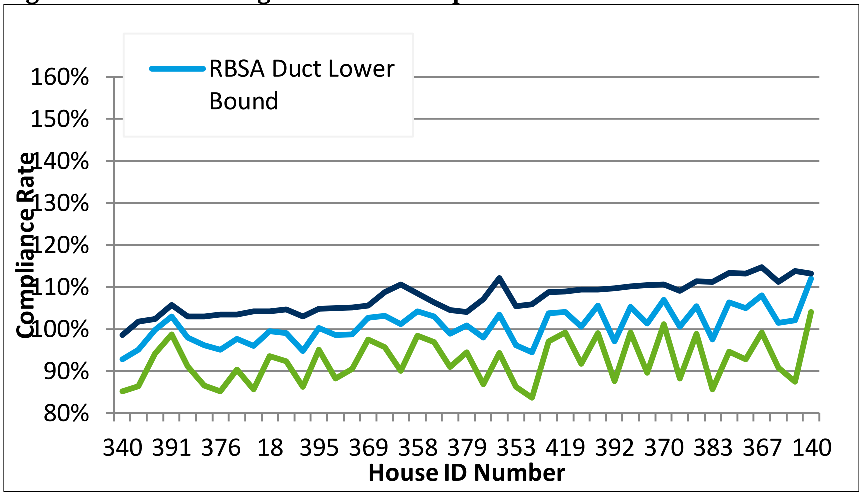
As shown in Figure 13, modeled results showed slightly higher compliance rates than RBSA data bounds. This would be expected because the RBSA data are for homes of all vintages in Idaho. Newer homes should have tighter duct systems than the average home in the existing housing stock.[21]

Figure 12. Infiltration Effect on Compliance Rate



[21] The figure only contains homes with duct systems outside of conditioned spaces.

Figure 13. Duct Leakage Effect on Compliance Rate



8. Findings and Recommendations

Study objectives included the following:

- Analyze and report current rate of energy code statewide compliance in new residential construction in Idaho, based on the Idaho version of the 2009 IECC.
- Review and comment on the various approaches for assessing code compliance.
- Determine aspects of current energy code in which enhanced code compliance would lead to the largest reductions in home energy consumption.
- Assess an approach to analyze code compliance based on the most significant items in determining energy impacts.

The study collected field data on sixty-nine Idaho homes permitted since the current residential code took effect and plans data from many of the same homes. Based on these data, Cadmus analyzed compliance using: the PNNL checklist approach, which did not measure compliance in terms of energy use; the significant item approach, which measured compliance based on the checklist items most significant to energy use; and a simulation model, providing a compliance measure based on energy use.

Cadmus' research also identified code requirements offering the most opportunity for increased energy savings, given enhanced compliance.

This chapter summarizes key findings addressing these issues, presenting recommendations for: improving code compliance; and conducting future compliance studies.

8.1. Discussion of Findings

8.1.1. Code Compliance

Idaho builders may select among three different approaches to demonstrate compliance with energy codes: prescriptive, tradeoff, and performance. There are several differences in the approaches that have significant impact in the results each generate. One is in how they handle lighting. Prescriptive and tradeoff approaches require homes to have at least fifty percent high-efficacy lighting, while the performance approach does not. Another difference involves the window efficiency requirements. The performance approach accounts for the amount of glazing, and limits the reference home, which establishes the energy budget for the standard, to a window-to-floor area ratio of fifteen percent. The prescriptive and tradeoff approaches do not account for the window area.

Idaho builders most commonly used a tradeoff compliance approach to demonstrate compliance. A little over one-half of builders used the tradeoff approach, and just over forty percent used the prescriptive approach. Only four percent of homes complied using the performance approach.

To assess the degree to which homes in Idaho complied with the new code, this study used three alternative methods to analyze compliance:

1. The PNNL checklist method: This approach was used to demonstrate and test the method developed by PNNL and made available for compliance analysis studies. It analyzed how well the studied homes complied with each process and efficiency requirement of the code.
2. The significant item method: This approach analyzed compliance based on only measures that were considered to have the most significant impact on energy use. It was evaluated as a less complex alternative to the complete checklist method.
3. The energy modeling method: This method estimated energy consumption of each as-built home relative to a reference home (that is, the same home built to code). Unlike the other two methods, it provided an estimate of energy use of each home compared to its consumption if built to just meet the code.

Table 19 shows statewide code compliance levels, determined using these three different methods. The PNNL checklist method provided an average compliance estimate equal to the ninety percent minimum target established in ARRA. Using the modeling approach, the compliance rate exceeded one-hundred percent, indicating homes on average performed better than homes just meeting the code minimum requirements. The significant item methodology gave the lowest compliance level, only eighty-three percent.

Table 19. Code Compliance Levels Determined by Three Methods

Methodology	Statewide Weighted Compliance Rate	90% Confidence Level Precision
Checklist	90%	3%
Significant Item	83%	4%
Energy Modeling (Heating/Cooling only)	109%	1%
Energy Modeling (with Lighting included)	100%	1%

All three methods indicated relatively high compliance with the Idaho residential code. The ARRA legislation establishes that states should strive to reach at least ninety percent compliance overall by 2017. Using the method developed by PNNL, compliance in Idaho is at the ninety percent level. The energy modeling approach indicates that compliance overall is at a level where residential energy use for space heating and cooling is less than if homes just met the code. When the effect of lighting is included, consumption is almost exactly what it would be if homes just met the code.

Both the checklist method and significant item method are bounded by one-hundred percent and provide no direct information about energy consumption. The energy modeling method has no bounds and the compliance rate calculated with this approach provides a direct indication of the energy impacts of code compliance.

The ninety percent minimum target in ARRA draws upon applying the PNNL checklist method, taking into account all code requirements, including those without direct effects on building energy use. Considering the relatively strict nature of the code and in effect in Idaho for only a short time, the compliance level estimated with this method presents a positive finding.

The precision (with a ninety percent confidence level) for estimated average compliance rates is shown in Table 19 (see page 38). The values are based on the variance observed in the compliance rates for the sampled homes. The effects of missing data (unobservable measures) on accuracy of compliance estimates are unknown–less than half the compliance items on the PNNL checklist were observable in almost two-thirds of homes in the sample. However, the study team believes the effects of unobservable items are not very large for the following reasons:

- When field-verified data were not available, but plans-verified data were, the study used the plans-verified data. As illustrated, the plans-verified values improve the compliance rate estimates under the assumption that they are correct at least half the time.

- In reviewing the checklist items that were unobservable, the team found that many were code requirements that were not clearly linked to energy use (such as labeling on insulation). In many cases, the lack of visibility resulted from the timing of the site visit and had no effect on energy use.

- When data were not available for a specific home, but were available for other homes in the same jurisdiction, the study used data from the other homes. Assuming building practices and code enforcement were fairly consistent within a jurisdiction, this approach helped fill data gaps accurately.

Based on the PNNL checklist compliance analysis:

- About ten percent of homes received a one-hundred percent compliance rate, based on the observable checklist items.

- Significant differences occurred between climate zones in the compliance rates of specific checklist measure categories.

- Only forty-two percent of homes met the lighting efficacy requirement, and installed lighting could not be observed in seventy-two percent of the homes.

- Fifty-six percent of items in homes that builders complied under the tradeoff or performance approaches were not observable during the team's site visits.

Based on the significant item compliance analysis:

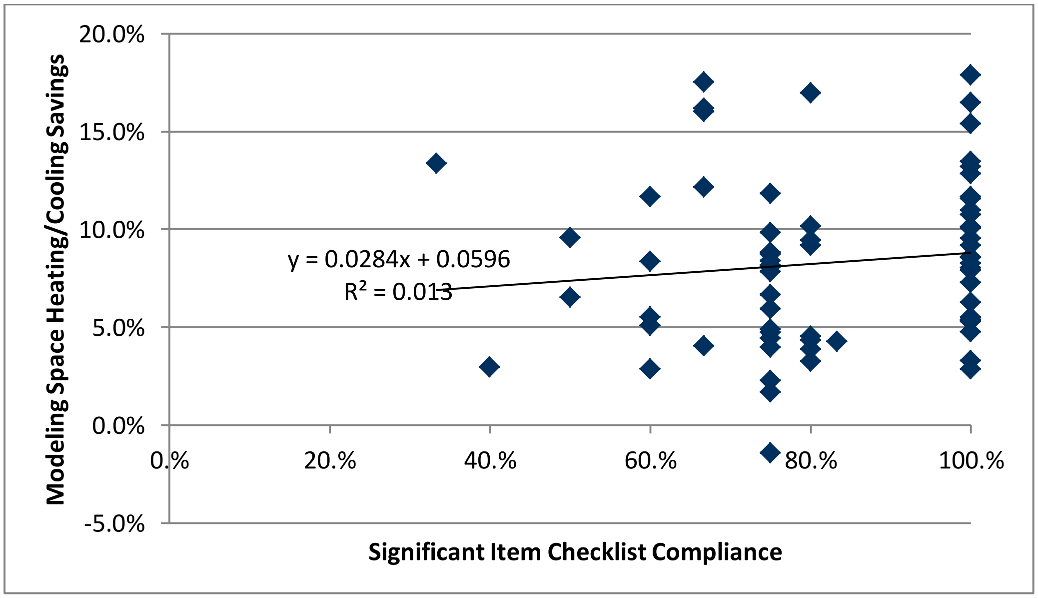
- About twenty-nine percent of homes received a one-hundred percent compliance rate, based on the observable checklist items.

- The average weighted compliance rate of eighty-three percent was lower than the PNNL checklist average rate of ninety percent.

The compliance estimates from the checklist and significant item methods were highly correlated (the correlation coefficient was 0.62, which is significant at better than the 0.0001 significance level). This suggested it should be possible to estimate checklist compliance reasonably accurately by determining compliance of a subset of only eight items.

As the simulation modeling compliance analysis requires additional labor, the study team explored whether the significant item compliance analysis method could be used to provide an accurate estimate of compliance rate energy impacts. To make this assessment, the study team calculated the percent savings for each home as-built compared to the modeled reference home. This value was regressed against the significant item checklist compliance rate for the same home. The results are shown in Figure 14. As the figure shows, there was only a very small positive correlation between the measures, and the relationship was not statistically significant. Consequently, the study team cannot conclude that the significant item compliance method can be used to assess compliance energy impacts.

Figure 14. Significant Item Checklist Compliance vs. Modeled Space Heating/Cooling Savings



The energy modeling analysis provided a more direct measure of compliance effects on energy consumption. Modeling results indicated homes as-built performed better than if built to just comply with code.

The following observations draw upon data used in the simulation analysis (see as shown in Figure 10, on page 33) and the analysis of lighting compliance:

- Better wall insulation or U-values than required by code contributed the most to overall envelope energy savings.
- More efficient windows than required by code made the second-largest contribution.
- The third largest contribution resulted from better attic insulation.
- Overall, floors and foundations exhibited lower insulation levels than required by the code. However, the models indicated these losses insufficient to counter gains from more efficient performing ceilings, walls, and windows.
- When lighting energy use was included with space heating and cooling energy, non-compliance with the lighting efficacy requirements caused a 10% decrease in overall energy compliance.

The modeling results also showed compliance, in terms of the percent energy savings, was remarkably consistent, regardless of a home's energy consumption. Estimates indicated almost all homes consumed zero to seventeen percent less than if built exactly to code requirements.

Several qualifications must be cited regarding the simulation model compliance analysis results:

- Data required to run the models were missing in many cases and Cadmus assumed components just met minimum code requirements in these cases. This assumption was made to avoid introducing either a positive or negative bias in the analysis.
- Due to a lack of data, actual duct leakage and infiltration rates could not be used in the analysis, though both can significantly affect energy use. The study sensitivity analysis based on available duct leakage and infiltration data showed that assuming both just met the code requirement was reasonable.
- The 2009 IECC did not provide credits for equipment efficiencies; so in predicting new home energy consumption, calculations assumed all homes would have minimally efficient equipment, a prediction likely to overestimate energy consumption.

8.1.2. Compliance Benchmarking

It is informative to compare Idaho compliance rates found in this study with energy code compliance rates from other studies. As this study illustrates, however, there are many ways to measure compliance and no standard metric has been widely adopted. Some of the alternative ways to measure compliance include the following:

- Pass/fail criteria for individual requirements or the code as a whole
- Percentage of requirements met
- Energy consumption relative to a building complying with the code.

Using energy consumption to measure compliance rates also can be further delineated based on a range of approaches such as these:

- Energy consumption as a percent of the consumption of a building just meeting the code
- The amount of energy a building uses that is more or less than a building built to code, calculated as the percent difference
- Percent a building saves of the amount of energy a building built to the current code would save relative to the prior code

In addition to these variations, assessment of compliance is confounded by the need to define what measures and energy impacts are included. As this study shows, lighting efficiency may or may not be a factor under the 2009 IECC depending on which approach a builder chooses to demonstrate compliance.

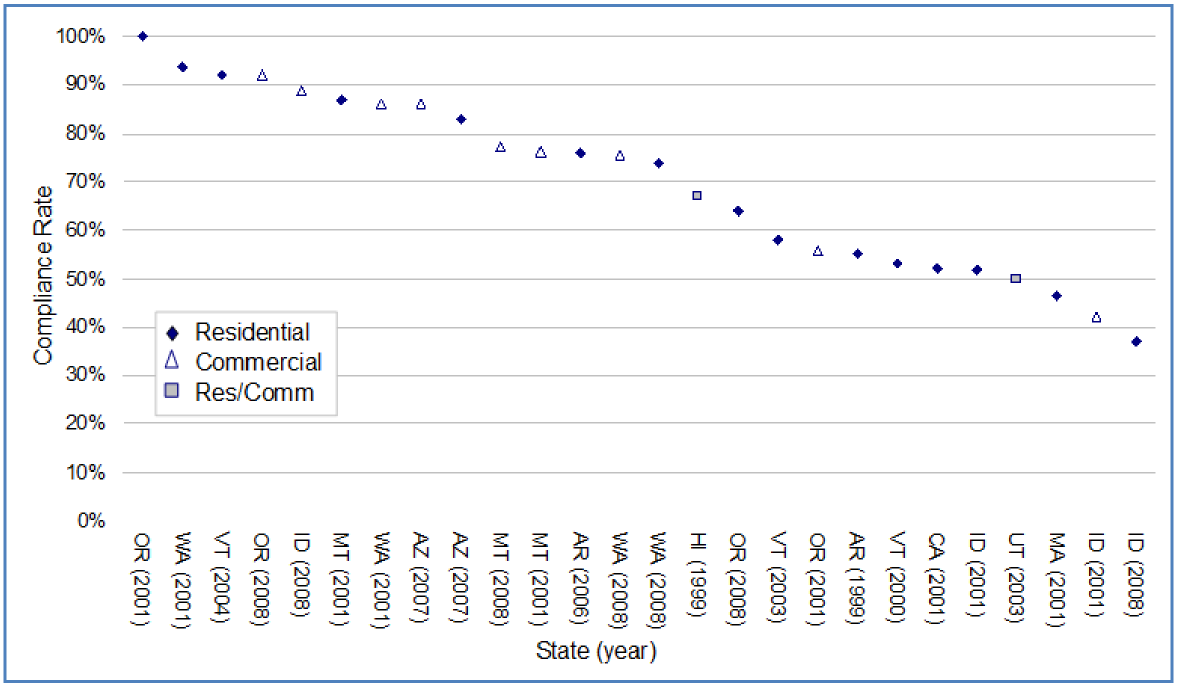
Despite these complexities and lack of consistency, compliance results from other studies provide context for the findings in this study. Figure 15 shows results of twenty-six prior studies for several states and residential and commercial buildings. The report noted that nine different compliance rate metrics had been used. The rates range from 100 percent to thirty-seven percent. Although the differences in methodology and metrics make meaningful comparisons challenging, it is informative that the lowest compliance rate shown is for Idaho residential buildings from a 2008 study. In spite of the comparability problems, comparing findings in the current study with the results shown in the figure for Idaho provides strong evidence that Idaho has made considerable progress in improving residential code compliance and enforcement. It is also useful to note that compliance rates above ninety percent have been measured in three studies in Oregon and Washington.

As mentioned before, NEEA sponsored a recent study of residential code compliance in Montana using methods similar to those used in this study, but without any energy impact estimates. The results from the Montana study and two other recent studies are shown in Table 20. They illustrate the diversity of methods used and the large compliance rate range observed in very recent studies.

8.2. Recommendations

The study team developed the following recommendations addressing three categories: code enhancement, facilitation of code compliance assessments, and the PNNL methodology.

Figure 15. Compliance Rates from Prior Studies, by State and Building Type



Notes: From Misuriello, Kwatra, Kushler, Nowak (2012)

Table 20. Recent Residential Code Compliance Study Findings

State	Study Date	First Compliance Method and Rate	Second Compliance Method and Rate	Third Compliance Method and Rate
Montana	2012	PNNL checklist—61%	Significant items—81%	Checklist items weighted based on estimated energy consumption impacts—64%
California	2008	Electricity space heating/cooling savings as percent of savings expected from code change—120%	--	--
Rhode Island	2012	PNNL checklist—58%	Prescriptive—38%	Energy cost— -26%

Notes: Montana results are from Lee, A., Cook, R., Horton, D. (2012); California results are from Cadmus (2010); Rhode Island results are from NMR Group, Inc., KEMA, Inc. The Cadmus Group, Inc., Conant (2012). Negative energy cost compliance for Rhode Island means the energy consumed by the average house exceeded what it would if the average home just met the code by twenty-six percent.

8.2.1. Code Enhancement

Despite observing relatively high statewide compliance levels using three different methods, Cadmus finds continued efforts appropriate to increase compliance levels in Idaho. Cadmus recommends NEEA increase its ongoing efforts to educate builders about the 2009 IECC. Specific recommendations include the following:

1. This study's findings should be communicated to builders and code officials.
2. Builders and code officials should be educated and trained in code requirements, especially those regarding floor and foundation insulation and lighting efficacy.
3. Efforts should seek to improve code compliance documentation provided to code officials.
4. Due to widespread use of the tradeoff approach, assistance should be provided to builders and code officials to ensure provision of accurate, documented tradeoff compliance analyses (for example, REScheck outputs), with checks against actual construction.

8.2.2. Compliance Assessments

In conducting this code compliance assessment, challenges emerged, and several steps can facilitate and enhance future studies. These steps, increasing the ease of conducting compliance assessments, will simultaneously increase energy simulation analyses' accuracy and completeness, based on the PNNL checklists. The following recommendations seek to facilitate future compliance studies:

1. Steps should be taken to reduce the difficulty of locating and visiting newly constructed homes.
   a) The state should investigate development of a statewide repository of code compliance data to facilitate code compliance tracking and future research.
   b) Building departments should be discouraged from discarding completed permits, and should be encouraged to assist in the evaluation process.
2. Maintaining permit documentation, including building blueprints and any results from energy modeling software such as REScheck on site during construction, can facilitate compliance reviews, and Idaho should require builders to retain such information on site until completing construction.
3. Any assistance the state could offer by working with builder organizations to urge builders to allow inspections in future compliance studies would greatly aid such studies.
4. For future compliance evaluation projects. Cadmus recommends conducting inspections in conjunction with building officials' final inspections, which would allow the most data to be gathered for each home. Thus, duct testing and HVAC efficiencies—both high-energy impact components—could be verified at each home.
5. To assess whether the assumptions made about items that were unobservable at the times homes were visited in this study, the study team recommends conducting a pilot study that follows a small number of homes through the entire construction cycle as described in the PNNL approach. This study would provide evidence about the validity of the assumptions made regarding compliance of unobservable items.
6. To supplement observable information collected at completed homes, Cadmus recommends infrared inspection of building envelopes to provide information about the

quality of insulation installation and air leakage.[22] Weighting a sample heavily toward finished homes and inspecting items not observable with infrared technology could allow for a more efficient use of field personnel.[23]

8.2.3. PNNL Methodology

PNNL has sought feedback on its proposed compliance assessment methodology, and has made continuous improvements. Using a common methodological approach for demonstrating compliance in all fifty states offers value, and the existing PNNL methodology provides an excellent foundation for further enhancements. The PNNL methodology can be modified to address remaining issues, per the following recommendations:

1. PNNL should investigate the option of using a less comprehensive checklist such as the eight significant item method examined in this study.
2. The weighting system used for PNNL's checklists should be refined to better reflect the greater importance of certain compliance issues. While the checklists currently value items as worth one to three points, a wider range would appropriately capture differences in the relative importance between various compliance items.
3. An energy-modeling component should be incorporated in PNNL's methodology. By combining PNNL's prescriptive checklist with more exact energy consumption metrics for newly constructed homes, evaluators could present a more robust view of compliance.

8.3. Final Observations

Although more remains to be done to increase code compliance in Idaho—both in terms of improving building practices and developing more advanced verification processes—Cadmus finds the state has made progress in implementing the latest residential energy code effectively to achieve relatively high compliance rates. Specific areas can be targeted to move toward achieving and demonstrating an overall ninety percent compliance rate for Idaho by 2017. However, the ultimate benefit of high code compliance rates is increased certainty of energy savings from the code; so the state should strive to achieve full compliance in all homes, and even exceed the code requirements.

9. References

Ecotope. 2012. *(RBSA)Residential Building Stock Assessment: Single-Family Characteristics and Energy Use*. Ecotope Inc. Presented to: Northwest Energy Efficiency Alliance.

Cadmus. 2010. *Codes & Standards (C&S) Programs Impact Evaluation, Volume III.* Prepared for: California Public Utilities Commission.

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[22] This would likely require winter visits to finished homes to obtain sufficient data because of the need for a large temperature differential between the building and outdoors.

[23] "RESNET Interim Guidelines for Thermographic Inspection of Buildings" April 2012.

Lee, A., Cook, R., Horton, D. 2012. *Montana Residential Energy Code Compliance.* Cadmus. Prepared for: Northwest Energy Efficiency Alliance.

Harry Misuriello, H., Kwatra, S., Kushler, M., Nowak, S. 2012. *Building Energy Code Advancement through Utility Support and Engagement.* American Council for an Energy-Efficient Economy.

NMR Group, Inc.; KEMA, Inc.; The Cadmus Group, Inc.; Conant, D. 2012. *Rhode Island 2011 Baseline Study of Single-Family Residential New Construction, Final Report.* Submitted to National Grid.

U.S. Census Bureau. Accessed 2012. Building Permits. http://censtats.census.gov/bldg/bldgprmt.shtml

U.S. Department of Energy. 2010. "Compliance Evaluation Checklists." Energy Efficiency and Renewable Energy. http://www.energycodes.gov/compliance/evaluation/checklists

U.S. Census Bureau. Accessed 2012. "How the Data are Collected (Survey of Construction)." http://www.census.gov/construction/nrc/how_the_data_are_collected/soc.html

U.S. Department of Energy. Accessed 2012. "Building Energy Codes Program." Energy Efficiency and Renewable Energy. www.energycodes.gov

U.S. Department of Energy. Accessed 2012. "Measuring State Compliance." Energy Efficiency and Renewable Energy. http://www.energycodes.gov/compliance/evaluation/checklists

Ibid. Section 5.2.

U.S. Department of Energy. 2010. "REScheck." Energy Efficiency and Renewable Energy. http://www.energycodes.gov/rescheck/

U.S. Department of Energy. Accessed 2012. State Sample Generator. http://energycode.pnl.gov/SampleGen/

10. Appendix A: Line Item Compliance

This Appendix presents results of sixty-nine DNV KEMA site visits for sixty-one compliance items on PNNL's checklist. For each checklist item, the following have been provided:

1. Construction phase (checklist section) of a compliance item.
2. Description of a compliance item.
3. The compliance item weight, assigned by PNNL.
4. The number of homes in which the compliance item was deemed compliant.
5. The number of homes in which the compliance item was deemed not compliant.
6. The number of homes in which the compliance item was not observed.
7. The number of homes in which the compliance item was not applicable.
8. The percentage of homes in which the compliance item was observed.
9. The percentage of observed homes in which the compliant item was verified.
10. The percentage of verified homes compliant with the item.

Table 21. Rate of Code Compliance by Compliance Criteria, All Homes

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
Pre-Inspection	Construction drawings and documentation available. Documentation sufficiently demonstrates energy code compliance, with the exception of HVAC loads, addressed in PR2. Systems serving multiple dwelling units must demonstrate compliance with the commercial code	3	62	5	2	0	100%	97%	93%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	HVAC equipment correctly sized per ACCA Manual J and S, or other approved methods: Heating system size(s): Cooling system size(s):	2	23	9	34	3	96%	48%	72%
Foundation	Slab edge insulation R-value.	3	3	0	5	61	12%	38%	100%
	Slab edge insulation installed per manufacturer's instructions.	3	0	0	14	55	20%	0%	-
	Slab edge insulation depth/length.	3	2	0	6	61	12%	25%	100%
	Conditioned basement wall exterior insulation R-value. If the insulation is located on the wall interior, use IN5 and mark this N/A. Not required in warm-humid locations in climate zone 3.	3	3	0	3	63	9%	50%	100%
	Basement wall exterior insulation installed per manufacturer's instructions.	3	2	0	4	63	9%	33%	100%
	Basement wall exterior insulation depth.	3	1	0	15	53	23%	6%	100%
	Crawl space wall insulation R-value.	3	7	0	1	61	12%	88%	100%
	Crawl space wall insulation	3	2	1	6	60	13%	33%	67%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	installed per manufacturer's instructions.								
	Crawl space continuous vapor retarder installed with joints overlapped by 6 inches and sealed, and extending at least 6" up the stem wall.	3	27	4	11	27	61%	74%	87%
	Crawl space wall insulation depth (total vertical plus horizontal distance).	3	4	0	7	58	16%	36%	100%
	Exposed foundation insulation protection.	2	0	0	11	58	16%	0%	-
	Snow melt controls.	2	0	0	2	67	3%	0%	-
Framing/ Rough-In	Door U-factor. One side-hinged door up to 24 ft2 can be exempted from the prescriptive requirements.	3	39	0	30	0	100%	57%	100%
	Glazing U-factor (area-weighted average). 15 ft2 of glazed fenestration, including skylights, may be exempted from the prescriptive requirements.	3	64	0	5	0	100%	93%	100%
	Glazing labeled for U-factor and SHGC (or default values used).	3	44	15	10	0	100%	86%	75%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	Skylight U-factor. 15 ft2 of glazed fenestration may be exempted from the prescriptive requirements.	3	1	0	4	64	7%	20%	100%
	Skylights labeled for U-factor and SHGC (or default values used).	3	1	1	3	64	7%	40%	50%
	Sunroom glazing U-factor. New windows and doors separating the sunroom from conditioned space must meet code requirements.	3	0	0	0	69	0%	0%	-
	Sunroom skylight U-factor.	3	0	0	0	69	0%	0%	-
	Mass wall exterior insulation R-value. If more than ½ of the insulation is on the wall interior, use IN3 and mark this N/A.	3	1	1	3	64	7%	40%	50%
	Mass wall exterior insulation installed per manufacturer's instructions.	3	1	0	5	63	9%	17%	100%
	Duct insulation. If all ducts are in conditioned spaces, mark this compliant. If all systems	3	51	0	18	0	100%	74%	100%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	are ductless, mark this N/A.								
	Duct sealing complies with listed sealing methods.	3	19	1	43	6	91%	32%	95%
	Duct tightness via rough-in. For post-construction tests, use FI4 and mark this N/A.	3	13	0	52	4	94%	20%	100%
	Building cavities NOT used for supply ducts.	3	2	6	12	49	29%	40%	25%
	IC-rated recessed lighting fixtures meet infiltration criteria.	2	13	2	51	3	96%	23%	87%
	HVAC piping insulation.	2	26	1	41	1	99%	40%	96%
	Circulating hot-water piping insulation.	2	7	0	61	1	99%	10%	100%
	Dampers Installed on all outdoor Intake and exhaust openings.	2	18	0	50	1	99%	26%	100%
	Fenestration that is not site built is listed and labeled as meeting AAMA /WDMA/CSA 101/I.S.2/A440 or has infiltration rates per NFRC 400 that do not exceed code limits.	1	40	7	22	0	100%	68%	85%
Insulation	Floor insulation R-value.	3	34	2	2	31	55%	95%	94%
	Floor	3	21	0	31	17	75%	40%	100%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	insulation installed per manufacturer's instructions, and in substantial contact with the subfloor.								
	Wall insulation R-value. If this is a mass wall with at least ½ of the wall insulation on the wall exterior, use FR10 and mark this N/A.	3	40	25	4	0	100%	94%	62%
	Wall insulation installed per manufacturer's instructions.	3	10	1	58	0	100%	16%	91%
	Conditioned basement wall interior insulation R-value. If the insulation is located on the wall exterior, use FO4 and mark this N/A. Not required in warm-humid locations in climate zone 3.	3	13	0	4	52	25%	76%	100%
	Basement wall interior insulation installed per manufacturer's Instructions.	3	8	0	11	50	28%	42%	100%
	Basement wall interior insulation depth.	3	2	3	13	51	26%	28%	40%
	Sunroom wall insulation R-value. New walls separating the sunroom from	3	1	0	0	68	1%	100%	100%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	conditioned space must meet code requirements.								
	Sunroom wall insulation installed per manufacturer's Instructions.	3	0	0	1	68	1%	0%	-
	Sunroom ceiling insulation R-value.	3	1	0	1	67	3%	50%	100%
	Sunroom ceiling insulation installed per manufacturer's instructions.	3	0	0	2	67	3%	0%	-
	All installed insulation labeled or installed R-value provided.	2	9	16	37	7	90%	40%	36%
	Air sealing complies with sealing requirements via visual inspection. If evaluated via blower door test, use FI17 and mark this N/A.	1	1	3	53	12	83%	7%	25%
Final	Ceiling insulation R-value. Where >R-30 is required, R-30 can be used if insulation is not compressed at eaves. R-30 may be used for 500 ft2 or 20% (whichever is less) where sufficient	3	62	3	4	0	100%	94%	95%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	space is not available.								
	Ceiling insulation installed per manufacturer's instructions. Blown insulation marked every 300 ft2.	3	13	4	52	0	100%	25%	76%
	Attic access hatch and door insulation.	3	18	2	49	0	100%	29%	90%
	Duct tightness via post construction. For rough-in tests, use FR14 and mark this N/A.	3	5	0	52	12	83%	9%	100%
	Heating and cooling equipment type and capacity as per plans.	3	13	6	46	3	96%	29%	68%
	Lighting - 50% of lamps are high efficacy.	3	8	11	50	0	100%	28%	42%
	Compliance certificate posted.	2	20	14	34	1	99%	50%	59%
	Wood burning fireplace - gasketed doors and outdoor air for combustion.	2	3	2	3	61	12%	63%	60%
	Programmable thermostats installed on forced air furnaces	2	20	0	46	3	96%	30%	100%
	Heat pump thermostat installed on heat pumps.	2	2	0	6	61	12%	25%	100%
	Circulating service hot water systems have automatic	2	13	0	45	11	84%	22%	100%

Construction Phase	Compliance Item	Item Weight	Number Compliant	Number Not Compliant	Number Not Observed	Number Not Applicable	Percent Observed	Percent Verified	Percent Compliant
	or accessible manual controls.								
	Automatic or accessible manual controls for heated swimming pools.	2	0	0	1	68	1%	0%	-
	Air sealing complies with sealing requirements via blower door test. If evaluated via visual inspection, use IN14 and mark this N/A.	3	2	0	58	9	87%	3%	100%
	Manufacturer manuals for mechanical and water heating equipment have been provided.	1	31	5	33	0	100%	52%	86%
	Timer switches on pool heaters and pumps.	1	0	0	0	69	0%	0%	-
	Heated swimming pool covers.	1	0	0	0	69	0%	0%	-

11. Appendix B: Derivation of Weights

As building codes vary significantly across climate zones, Cadmus treated climate zones as a stratification variable in analyzing results. Within each climate zone, Cadmus treated counties as level-one sampling units, and individual building starts within counties as level-two sampling units.

This section utilizes the following notation:

- Climate zones indexed with the letter *i*.
  - M_i as the population size (i.e., total number of building starts) for zone i.
- Counties indexed with the letter *j*.
  - N_j as the population size (i.e., total number of building starts) for county *j*.
  - n_j as the sample size for county *j*.
- Building starts indexed with the letter *k*.
  - $x_{j,k}$ as the compliance rate for the *k*th building in county *j*.

Cadmus estimates the compliance rate for the *j*th sampled county as:

$$\overline{x}_j = \sum \frac{x_{j,k}}{n_j} \text{ (The sum is over sampled buildings } k \text{ within county } j.\text{)}$$

For each climate zone, Cadmus estimated the compliance rate as the weighted mean of rates for sampled counties within that zone. For example, zone *i* is:

$$\overline{\text{Zone}}_i = \frac{\sum N_j \cdot \overline{x}_j}{\sum N_j} \text{ (Both sums are over sampled counties } j \text{ within zone } i.\text{)}$$

In terms of weighting, this means, in estimating a climate zone's compliance rate, the weight attached to the sample point $x_{j,k}$ equals:

$$w_{j,k}^{\text{climate}} = \frac{N_j}{n_j}$$

The regional compliance rate could be estimated as the weighted average of the climate zone compliance rates:

$$\overline{\text{Region}} = \frac{\sum M_i \cdot \overline{\text{Zone}}_i}{\sum M_i} \text{ (Both sums run over the four regional climate zones.)}$$

In terms of weighting, this means, in estimating the regional compliance rate, the weight attached to the sample point $x_{j,k}$ as:

$$w_{j,k}^{\text{region}} = \frac{M_i}{\sum_{\substack{\text{sampled } j \\ \text{in zone } i}} N_j} \cdot \frac{N_j}{n_j} \text{ (Here, } i \text{ is the climate zone containing county } j.\text{)}$$

12. Appendix C: PNNL Checklist

A sample PNNL checklist for climate zone 5 is presented in this appendix as an embedded file.

NEEA Residential Checklist ID.pdf

13. Appendix D: Lighting Consumption Calculation

Estimated lighting energy consumption was calculated using secondary data sources for the 2012 RBSA, RTF data and from primary site visit data. The following factors were used to estimate lighting energy consumption:

- Heating and Cooling Enegy Consumption (HCEC) – This is the average per home heating and cooling energy consumption from the SEEM model outputs.
- Non - Compliant Lighting Energy Consumption (ncLEC) –This factor is calculated from RBSA data from Idaho using 63.6[24] lamps per home. A typical distribution of incandescent lamp wattages from RTF data[25] was used to determine the average installed lighting load of a home lit by incandescent lights of 3,755 watts. Hours-of-use was determined using RTF calculator[26] data with an average daily use of 2.02 hours-day. A factor of 3.16 was applied to the result to adjust accordingly for the source energy factor required by the IECC compliance methodology.
- Compliant Lighting Energy Consumption (cLEC) –This factor is calculated from RBSA data from Idaho using 63.6[27] lamps per home. A typical distribution of 50% incandescent and 50% CFL lamp wattages from RTF data[28] was used to determine the average installed lighting load of a home lit by incandescent lights of 2,332 watts. Hours-of-use was determined using RTF calculator[29] data with an average daily use of 2.02 hours-day. A factor of 3.16 was applied to the result to adjust accordingly for the source energy factor required by the IECC compliance methodology.
- Lighting Compliance Rate (LCR) – The LCR is the percentage of homes in this study with at least 50% high efficacy lighting fixtures installed.

The equation used to calculate total energy consumption with lighting installed follows:

$$HCEC + [(ncLEC \times (1 - LCR)) + (cLEC \times LCR]) = Total\ Energy\ with\ Lighting$$

The total compliance rate was then calculated using the compliance rate equation:

$$\frac{Energy\ Usage\ Reference\ Home}{Energy\ Usage\ As\ Built\ Home} = Compliance\ Rate\ \%$$

[24] Ecotope. 2012. *(RBSA)Residential Building Stock Assessment: Single-Family Characteristics and Energy Use*. Ecotope Inc. Presented to: Northwest Energy Efficiency Alliance.

[25] Northwest Council. 2012 (RTF) *Regional Technical Forum: Residential Lighting - CFL*

[26] Northwest Council. 2012 (RTF) *Regional Technical Forum: Residential Lighting - CFL*

[27] Ecotope. 2012. *(RBSA)Residential Building Stock Assessment: Single-Family Characteristics and Energy Use*. Ecotope Inc. Presented to: Northwest Energy Efficiency Alliance.

[28] Northwest Council. 2012 (RTF) *Regional Technical Forum: Residential Lighting - CFL*

[29] Northwest Council. 2012 (RTF) *Regional Technical Forum: Residential Lighting - CFL*