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Residential Energy Code Sampling and Data Collection Guidance for Project Teams

DRAFT

April 2015

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

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Summary

The U.S. Department of Energy (DOE) requested that the Pacific Northwest National Laboratory (PNNL) modify procedures released in March 2010 (PNNL 2010) to support the federal Funding Opportunity Announcement (FOA), “Strategies to Increase Residential Energy Code Compliance Rates and Measure Results.”¹ The FOA requires states to complete the following activities:

- measure the pre-program compliance rate using a DOE-developed methodology that provides state-wide results with 90/10 statistical reliability;
- implement education, training, and outreach activities designed to increase code compliance; and
- measure the post-program compliance rate using the same methodology as the pre-program study.

The methodology is currently being revised with consideration of stakeholder comments received through a recent DOE Request for Information (RFI)² as well as lessons learned through related studies. This document is intended to serve as a working set of procedures for studying residential energy use under the referenced FOA. As a working document, it also provides an opportunity for projects supported under the FOA (Project Teams) to provide valuable feedback to DOE to ensure that the final version can be implemented in a practical manner and will achieve the stated goals of the FOA.

The current guidance introduces several important changes relative to the 2010 methodology (PNNL 2010), including:

- limiting applicability solely to **new, site-built single-family homes**, as opposed to the inclusion of both new and existing residential and commercial buildings;
- shifting the unit of analysis from homes to **individual code requirements**;
- a **sample size of 63** for each of the individual code requirements discussed below;
- a data collection form based on a **single site visit** rather than four visits; and
- the addition of an **energy savings metric**; specifically, the measurement of the change in energy use from the pre-education/training/outreach phase to the post- phase based on a set of code requirements that can be modeled through energy simulation.

¹ See <https://eere-exchange.energy.gov/FileContent.aspx?FileID=e6fd3f56-d6cc-4db3-8d26-6b52c4e9c27a>.

² See <https://www.federalregister.gov/articles/2013/08/06/2013-18952/doe-activities-and-methodology-for-assessing-compliance-with-building-energy-codes>.

Acronyms and Abbreviations

ACH	air changes per hour
cfm	cubic feet per minute
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
FOA	funding opportunity announcement
ICC	International Code Council
IECC	International Energy Conservation Code
IRC	International Residential Code
PNNL	Pacific Northwest National Laboratory
RFI	request for information
SHGC	solar heat gain coefficient

DRAFT

Contents

Summary	iii
Acronyms and Abbreviations	v
Contents	vii
Tables	vii
Introduction.....	1
Individual Project Steps	4
Step 1. Develop Initial Sampling Plan.....	4
Step 2. Conduct Stakeholder Meeting	5
Step 3. Develop Final Sampling Plan.....	5
Step 4. Contact Jurisdictions and Identify Homes to Sample.....	6
Step 5. Collect Field Data.....	7
Step 6. Analyze and Report Field Data	8
Step 7. Conduct Education, Training, and Outreach	8
Step 8. Re-Evaluate	8
References.....	10
Appendix A Questions to be Addressed at Stakeholder Meetings.....	A.1
Sampling Plan Discussion	A.1
Data Collection Form	A.2
Project Team Support and Relationships.....	A.2
Schedule	A.2

Tables

Table 1. Project Steps	4
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Introduction

The goal of the U.S. Department of Energy (DOE) Funding Opportunity Announcement (FOA) “Strategies to Increase Residential Energy Code Compliance Rates and Measure Results”³ is to determine whether an investment in education, training, and outreach programs can produce a significant, measurable change in single-family residential building code energy use, and therefore energy savings, within 2-3 years. Participants in the eight states (Alabama, Arkansas, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, and Texas) will:

- measure the pre-program compliance rate using a DOE-developed methodology that provides state-wide results with 90/10 statistical reliability.
- implement education, training, and outreach activities designed to increase code compliance.
- measure the post-program compliance rate using the same methodology as the pre-program study.

DOE requested that the Pacific Northwest National Laboratory (PNNL) modify the procedures released in March 2010 (PNNL 2010) to support projects funded through the referenced FOA. The methodology is currently being revised with consideration of stakeholder comments received through a recent DOE Request for Information (RFI)⁴ as well as lessons learned through current and previous studies. This document is intended to serve as a working set of procedures for studying residential energy use under the referenced FOA. As a working document, it also provides an opportunity for Project Teams to provide valuable feedback to DOE to ensure that the final version can be implemented in a practical manner and will achieve the stated goals of the FOA.

The current guidance introduces several important changes relative to the 2010 methodology (PNNL 2010), including:

- limiting applicability solely to **new, site-built single-family homes**, as opposed to the inclusion of both new and existing residential and commercial buildings;
- shifting the unit of analysis from homes to **individual code requirements**;
- a **sample size of 63** for each of the individual code requirements discussed below;
- a data collection form based on a **single site visit** rather than four visits; and
- the addition of an **energy savings metric**; specifically, the measurement of the change in energy use from the pre-education/training/outreach phase to the post- phase based on a set of code requirements that can be modeled through energy simulation.

To determine the sample size needed for acceptable statistical accuracy of the new energy savings metric, PNNL identified the building components with the largest direct impact on energy use based on

³ See <https://eere-exchange.energy.gov/FileContent.aspx?FileID=e6fd3f56-d6cc-4db3-8d26-6b52c4e9c27a>

⁴ See <https://www.federalregister.gov/articles/2013/08/06/2013-18952/doe-activities-and-methodology-for-assessing-compliance-with-building-energy-codes>.

the prescriptive and mandatory requirements of the 2009 International Energy Conservation Code (IECC) (ICC 2009).⁵

These *key* items are:

1. envelope tightness (expressed in air changes per hour measured at 50 Pascal);
2. window solar heat gain coefficient (SHGC);
3. window U-factor;
4. exterior wall insulation;
5. ceiling insulation;
6. fraction of high-efficacy lighting;
7. foundation insulation (floor/basement wall/slab insulation); and
8. duct leakage.

All of the above except “duct leakage” were analyzed⁶ using the PNNL national prototype⁷. For purposes of this analysis, floor insulation, basement wall insulation, and slab insulation were combined into a single category of foundation insulation. The building components in the numbered list above are referred to as key items in the remainder of this document.

The study sample requires a minimum of 63 observations for each of the key items to achieve the goal of detecting statistically significant differences in energy use comparing state averages before and after education, training and outreach activities. Beyond the key items, every attempt should be made to collect all additional data as specified in the PNNL data collection forms, although “non-key” items do not have a minimum number of observations required for the study. In the current guidance, researchers only visit each home once because the knowledge that energy code data is being collected may influence the builder to be more conscientious after the first visit and thus bias the results. Going to each house once means that many more than 63 homes will need to be visited to obtain the required observations for each of the key items. DOE and PNNL will be in frequent communication with the Project Teams while field data is being collected, and will work with the teams to determine the most effective sampling strategy.

The approach to selecting homes represents another important change relative to previous DOE guidance. In the updated approach, homes are randomly visited until 63 observations are obtained for one of the key requirements. After that, homes are pre-screened to ensure that they are in the phase of construction where the remaining requirements will be observable. The pre-screening will become

⁵ DOE chose the 2009 IECC as the most commonly used code for the 8 states involved in the FOA. One state (Maryland) uses the 2012 IECC and other states make use of the International Residential Code (IRC) or state-specific alternatives, but the 2009 IECC appeared most appropriate for these calculations.

⁶ Duct leakage analysis requires an additional step in the PNNL analysis and it was not possible to conduct this step for the thousands of simulations used to generate the sample size. However, duct leakage will be included in the analysis of field data discussed in Step 6 below.

⁷ Available at http://www.energycodes.gov/development/residential/iecc_models. The energy impact of duct leakage could not be sufficiently captured by the analysis due to limitations of energy simulation software and computational constraints.

increasingly comprehensive until just one key requirement remains, after which only homes which exhibit that particular requirement need be visited. There is always a trade-off between an ideal simple random sampling approach and feasibility in the field. Within the current guidance, DOE believes that this approach will not introduce a systematic bias into the results, and will make the sample collection process as streamlined as possible.

To illustrate this idea in a simplified manner, assume that 63 samples each are needed only for ceiling insulation, wall insulation, and window SHGC. After field technicians randomly visit 80 homes, they have observed ceiling insulation in 10 homes, wall insulation in 63 homes and window SHGC results in 25 homes. Having reached their quota for wall insulation, they would begin pre-screening homes to ensure that they only visit those where either ceiling insulation is still observable or window SHGC is available. After visiting another 30 homes they obtain 63 observations for SHGC; at this point they would pre-screen to ensure that all remaining homes they visit have ceiling insulation observable. (Note that they would continue to collect information about the other items if they are observable, which would increase the level of confidence in the results.)

A blower door test and duct leakage test are required on every home. RESNET protocols will be used by the Project Teams. Duct testing should be conducted at the final stage (as opposed to rough-in). Teams may choose to test homes during the rough-in stage, however, these values will be used only for informational purposes, and cannot fulfill the key item – a minimum of 63 homes need to be tested during the final stage of construction. Test results will only be shared with the builders upon request, not code officials.

Individual Project Steps

The steps and activities for which PNNL and the individual Project Teams are responsible are shown in Table 1. These steps are completed twice; once before the Project Teams conduct education, training and outreach activities, and once afterward. PNNL will compare the pre- and post-results to determine if there are statistically significant differences in simulated energy use can be detected.

Table 1. Project Steps

Step	Activity	Responsibility
1	Develop initial sampling plan	PNNL
2	Conduct stakeholder meeting	Project Team
3	Develop final sampling plan	PNNL
4	Contact jurisdictions and identify homes to sample	Project Team
5	Collect field data	Project Team
6	Analyze and report field data	PNNL
7	Conduct education, training and outreach	Project Team
8	Re-evaluate	PNNL and Project Team

Step 1. Develop Initial Sampling Plan

Responsibility: PNNL

PNNL will develop an initial sampling plan for discussion at the stakeholder meetings described in Step 2. The plan will be based on Census Bureau data⁸ and will specify the number of sets of the key code elements that need to be observed in each place in the state. Census Bureau data is available at the county and place⁹ level, and PNNL will develop the initial sampling plan using a proportional random sample approach¹⁰ on the place-level data. PNNL will calculate the average number of single-family homes constructed in each place over the last 3 years, and use that number as the basis of the proportional random sample. It is important to keep in mind that the sampling plan specifies the number of observations of each key item that must be made in each selected place. The number of homes that must be visited in each place will be larger than the number of observations. The reason the number of homes visited is larger than the number of observations required is that each home is visited only once and not all of the key items can be observed at each home. The actual number of homes that will need to be visited is not predictable in advance (see the related discussion in Step 4).

⁸ Census Bureau data may be found at <http://censtats.census.gov/>. Select the “Building Permits” data. Documentation on how this data is obtained may be found at the same link.

⁹ “Places” are cities and areas within counties. These “places” may or may not correspond to jurisdictions.

¹⁰ A proportional random sample is based on a list (in this case of new home permits) that has one entry for each estimated new home permit in each place. Thus, if a state is estimated to have an average of 500 new home permits a year, and Place “X” has 100 of those permits, the list will have 500 entries, of which 100 will be for “Place X”. This list will be randomly sampled until the minimum required sample size is achieved.

The initial sampling plan will be focused solely on achieving a statistically significant sample at the state level. If there are any special considerations within a state (such as suspicions of systematic energy code implementation differences across county or climate zone boundaries), these need to be discussed at the stakeholder meeting.

The initial sampling plan will also take into account the number of code versions involved in each state. If there are multiple codes involved in a state, the initial sampling plan can be adjusted accordingly. However, the sample size in a state will increase as the number of codes increases which will have significant budget implications. This issue will need to be discussed at the stakeholder meeting for any state with multiple codes.

Step 2. Conduct Stakeholder Meeting

Responsibility: Project Team

The Project Team responsible for each state will conduct a stakeholder meeting of all interested and relevant stakeholders in that state. The list of stakeholders should include (but is not limited to) state code officials, local code officials, contractors to the Project Team, builders, subcontractors, material supply distributors, designers, energy advocacy groups, and utility representatives. DOE and PNNL will participate in person at each stakeholder meeting to present and get feedback on the initial sampling plan. Following the stakeholder meeting, PNNL will develop a final sampling plan. The topics for discussion at the stakeholder meeting are listed in Appendix A, and include the sampling plan, the data collection form, Project Team support and relationships, and the project schedule.

Step 3. Develop Final Sampling Plan

Responsibility: PNNL

Based on input received at the stakeholder meeting, PNNL will work with the Project Team to develop a final sampling plan and data collection form. Each state is unique and there may be good reasons to modify the initial sampling plan or even replace it in its entirety. Project Teams should look critically at the initial sampling plan to make sure the initial plan is acceptable. The key is that the sampling plan must be representative of the entire state or that portion of the state that has been selected for the project. Changes to initial sampling plans may be needed for several reasons, including:

- 1) Census Bureau permit data may not cover the entire state; perhaps some counties do not issue building permits. Counties that do not issue building permits would not report any building permits to the Census Bureau. A possible solution would be to identify permits from another source within the state (e.g., plumbing system, HVAC system permits, etc.) that can be used to construct an alternative random sample that covers the entire state.
- 2) Census Bureau data may cover the entire state, but travel to some remote locations may be overly burdensome. A possible solution would be to substitute a less remote location for a more remote location, ensuring that the substitution is still representative.
- 3) The state may have large sections of unincorporated areas where building permits are issued but no further code enforcement is conducted. Given that the unincorporated areas do represent what is happening in the state, one solution may be to encourage the Project Teams to try to sample

these areas even if it may be harder to get contact information for homes. Ignoring the unincorporated areas would not be representative of the state.

- 4) The state may desire a sampling plan for a limited geographic area of the state. If the initial sampling plan was done for the entire state using Census Bureau data (or other state-specific permit data), with DOE's approval, PNNL would be able to develop a sampling plan that focuses only on a specified part of the state. The Project Team would need to be able to describe what parts of the state they wish to cover.
- 5) The state may be trying to develop a sampling plan for a limited geographic area of the state that serves as a representation for the whole state. If there are issues such as differences in the fraction of permit activity in unincorporated areas in the limited geographic area versus the fraction of permit activity in unincorporated areas in the state, it would be possible for PNNL to adjust the sampling plan to assign a specific fraction of the samples to the unincorporated areas.

Step 4. Contact Jurisdictions and Identify Homes to Sample

Responsibility: Project Team

Once the Project Team has received the revised sampling plan and data collection form and is ready to begin site visits, they will contact the jurisdictions to be sampled and request a list of all homes permitted under the current code that 1) are currently under construction, or 2) have been recently constructed (defined as any homes that have received their permit within the past 12 months, but are not yet occupied)¹¹. Owner-occupied homes will not be included in this activity. Ideally, the information provided by the jurisdiction will include documentation of the specific energy code path used and current stage of construction for each home. Code officials have no other role in the project other than to provide this information. Code officials are not to be involved in on-site data collection activities.

While the Census Bureau (or other) permit data identifies the places that need to be included to produce statistically representative results, it cannot identify the actual permitting jurisdictions for each place nor can it be used to identify specific homes that are suitable for sampling. The Project Team should construct its own proportional random sample of the homes available for sampling in the jurisdiction (similar to the proportional random sampling process used to generate the jurisdictional sample in Step 1). The Sampling Plan identifies how many complete sets of observations must be made in each jurisdiction in order to generate statistical significance on a statewide basis. In some jurisdictions, obtaining the necessary sets of observations may mean visiting 2-3 times as many homes or more. The objective of the study is to obtain 63 observations for each key item, which is the sum of the required number of observations across the sampled jurisdictions.

To minimize sample bias, the Project Team should follow the four steps below. Jurisdictions and builders should never be allowed to select specific homes to visit.

1. From the jurisdiction, obtain a list of all homes under construction or built to the code(s) being analyzed.

¹¹ If the list of homes permitted within the last 12 months is not at least 6 times the number of samples needed in that jurisdiction, then a list of homes permitted within the last 18 months should be requested.

2. Enter all those homes in an Excel spreadsheet.
3. Assign each home a number from 1 to the total number of homes on the list.
4. Use Excel's random number generator function to pick random homes from the list.

For example, if a jurisdiction has 100 homes available and the Project Team needs to sample 10 homes, the Project Team would create a list of all 100 homes in Excel, number them 1 to 100, and then use the Excel random number function of “=RAND()” 100 times to get a complete list of homes with random number. The random numbers should be copied to a new column and pasted as values. The columns containing the list of homes and the random number values should then be sorted based on the random number value from smallest to largest. The first 10 homes on the list are the first 10 that should be sorted. If additional homes are needed for whatever reason, the next homes on the sorted list should be selected.¹²

Gaining access to the homes is an important step in the process and has proven challenging in past activities. Project Teams may wish to consider if they need to augment their Project Team with “relationship managers” to address this step. One approach that has been used successfully in some studies is the hiring of well-known, retired building officials to act as liaisons to the building departments. Project Teams are encouraged to document best practices and lessons learned.

Step 5. Collect Field Data

Responsibility: Project Team

The Project Team will collect the field data using the data collection form provided by PNNL (in Excel)¹³. The data collection form is based on the requirements of the IECC and the key items targeted by the study, with items added or subtracted for state-specific codes, and includes additional items needed for energy simulation. The Project Team will go to the first home on the list developed in Step 4, collect all the available information required on the data collection form, move on to the next home on the list and repeat the data collection effort until the designated number of samples are obtained for that place as identified in the sampling plan, and then will repeat the process for the next place. Once the data has been collected on the forms¹⁴, the Project Team will enter it into a web-based data entry tool provided by PNNL. Permission to access the central database will be controlled by a representative of the Project Team. PNNL will offer an online training session on the data collection form and the associated web-based data entry tool and will be available to help individual teams as needed. No personally identifiable information will be provided to PNNL. The data collection form includes only a coded identification number to be assigned to each home (in this format: two-digit state abbreviation + a unique number assigned by the project team).

¹² Assistance from PNNL in this activity may be requested.

¹³ The data collection form is provided electronically in Excel format. The Project Team may enter data into the form using a computer, or they may print the form out and enter the data on paper forms.

¹⁴ The Project Team may enter data into the web-based data entry tool at any time through the end of the data collection period.

Step 6. Analyze and Report Field Data

Responsibility: PNNL

Project Teams are responsible for determining the specific homes to visit, collecting data from those homes, reviewing data quality, and entering the data into the PNNL web-based tool. PNNL will perform the analyses, including:

1. Determining the distribution of field observations for individual code requirements, based on the code requirements in the data collection form and the energy metrics. Individual requirements with implementation issues and large energy impacts will be highlighted.
2. Analyzing building geometry to develop one or more state-specific prototype homes.
3. Simulating state-specific prototype homes to determine the energy differential between the homes sampled and code-compliant homes.
4. Comparing pre-post for the evaluation of significant energy savings (after Step 8).

PNNL will provide the Project Team with a report detailing the analysis results on a statewide basis. The purpose(s) of the report on pre-outreach results are to 1) determine a baseline energy use estimate and 2) increase the effectiveness of the Project Teams' education, training, and outreach activities (Step 7) by identifying code requirements that are not being met and which have the biggest impact on energy usage.

Step 7. Conduct Education, Training, and Outreach

Responsibility: Project Team

Project Teams will provide education, training, and outreach in accordance with their approved project work plans with the intent of addressing energy code implementation issues found in the pre-project study. The Project Teams may request assistance from PNNL including curricula, materials or other resources as stated in the FOA.

Step 8. Re-Evaluate

Responsibility: As above for each step

Once the Project Team has completed Step 7, the process will be conducted again, with the latest available permit data, new county-level and place-level sampling plans from PNNL, and a new stakeholder meeting conducted by the Project Team. The data collection form will remain the same unless issues are found during the initial study.

One specific situation that may occur between the initial study and the final study is that a state may update its energy code. In order to maintain the integrity of the results and fulfill the objective of being able to compare pre- and post-results, it will be necessary for states to evaluate with the same energy code both before and after education, training, and outreach efforts.¹⁵

¹⁵ This comment applies strictly to the “meets/does not meet” requirements found in all energy codes. Requirements with numerical values can be analyzed as compliant or not compliant even if the state changes its energy code.

It is also possible that federal minimum equipment efficiencies for residential heating, cooling, and water heating equipment could change during the FOA project. This would not impact code implementation directly but would change the simulation modeling required for energy analysis. If this occurs, PNNL will use the minimum efficiency requirements in place at the time of the initial study for the final study. Evaluators will collect the actual efficiency of the installed equipment so if it becomes necessary, different analyses could be done using the old federal standard, the new federal standard or the actual equipment.

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PNNL – Pacific Northwest National Laboratory. 2010. *Measuring State Energy Code Compliance*. <http://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf>.

Appendix A

Questions to be Addressed at Stakeholder Meetings



The following questions are to be addressed at the stakeholder meetings.

Sampling Plan Discussion

1. What is the relationship between the “places” identified by the Census Bureau and the jurisdictions that must be contacted for sampling purposes?
2. Can all the “places” be sampled?
3. Is there any part of the state that is not adequately covered by the Census Bureau data? (In an evaluation done for Montana, it was discovered that approximately half the homes were constructed outside of any code-enforcing jurisdiction, and therefore Montana homes were not well represented by the Census Bureau data.)
4. If there is a part of the state that is not adequately covered by the Census Bureau data, how could that part of the state be sampled? (In the Montana study, data on new electrical hookups was obtained from state permits and used to develop the sample.)
5. Is there additional data besides the Census Bureau data that should be included in the sampling plan?
6. Is there any reason to apportion part of the state sample to any particular climate zone in the state? (For example, if one climate zone has significantly different envelope requirements.)
7. Is there any reason to use something other than 3 years of Census Bureau data in the initial sampling plan? (For example, if expected future construction is better reflected by the most current year rather than the average of the last 3 years, perhaps the most current year should be used.)
8. Are there multiple codes in use within the state? (States that are home rule states may have multiple codes adopted. States may also have stretch codes adopted in some parts of the state.) If so, how should the sampling plan be modified? (One approach is to consider each section of the state with a specific code as a “mini-state” and to sample each “mini-state” as if it were a state. This will increase the total sample size within the state.)
9. Are there any proposed sampling locations that are so remote that they should be replaced by similar locations that are less cost prohibitive? (In a strict proportional random sample, a very small jurisdiction that is isolated geographically may be chosen for the sample. With care, this location could be replaced with a location with similar characteristics that is not as remote in order to reduce travel time for the Project Team. This substitution must be done thoughtfully to avoid introduction of bias into the sample.)
10. Are there any proposed sampling locations that have other problems associated with them? If so, should these locations be avoided? (There could be jurisdictions that are notably uncooperative or other problems which would limit the Project Teams’ ability to gather complete and valid data.)

Data Collection Form

As part of the initial sampling plan, PNNL will develop a state-specific data collection form that will include input fields for all of the information needed to complete the study. These forms will be based on the forms used for the previous 2010 pilot studies¹⁶, but with the inclusion of additional information needed to document energy-related attributes of the home that are not addressed through specific code provisions¹⁷.

1. Does the information required on the data collection form to identify the home match the information that is available from jurisdictions?
2. Does the data collection form contain all energy code requirements for the state?
3. Does the data collection form contain any information that does not need to be collected?
4. Does the data collection form lack any information that should be collected?
5. Who will be the representative of the Project Team who controls access to the Project Teams' data in the central database?

Project Team Support and Relationships

1. What are the roles, responsibilities, and coordination of the Project Team and its contractors?
2. Does the Project Team have the support of all necessary stakeholders?
3. Does the Project Team have good relations with the jurisdictions to be sampled?
4. How will the Project Team go about contacting jurisdictions?
5. Does the Project Team have good relations with the building community, either on its own or through the jurisdictions to be sampled?
6. Does the Project Team have all the capabilities needed to conduct the evaluation? (All teams need the capacity to do blower door testing and duct leakage testing.)
7. How can we maximize the number of homes we can gain access to?

Schedule

1. What is the Project Team overall schedule for the project?
2. When does the Project Team anticipate contacting jurisdictions to sample?
3. When does the Project Team anticipate beginning field data collection?
4. When does the Project Team anticipate ending field data collection?
5. When does the Project Team anticipate beginning data entry?
6. When does the Project Team anticipate ending data entry?

¹⁶ See <http://www.energycodes.gov/compliance/evaluation/checklists> for details of the 2009 IECC and 2012 IECC checklists that will be the basis of the data collection form used in this methodology.

¹⁷ Items for example, such as home geometry and mechanical equipment.



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