Massachusetts Energy Code Pilot Report

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Massachusetts Residential New Construction Program Administrators

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Northeast Energy Efficiency Partnerships

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Executive Summary

This project field tested the protocol developed by Pacific Northwest National Laboratory (PNNL), as part of the US Department of Energy (DOE) Building Energy Code Program (BECP), for verifying energy code compliance. The core of the PNNL protocol is a checklist designed to be completed during on-site inspections at various construction stages. The 2006 International Energy Conservation Code (IECC) checklist developed by PNNL was completed for two groups of homes: 50 non-ENERGY STAR®-qualified homes completed at the end of the 2006 IECC cycle in Massachusetts and 50 ENERGY STAR-qualified homes certified in the 2010 Massachusetts New Homes with ENERGY STAR® Program.

Compliance rates using the checklist are compared to compliance rates under three other compliance pathways: the Overall Building UA[1] (REScheck™) compliance path, the performance based Home Energy Rating (HERS Index) and Annual Energy Cost compliance paths. Compliance rates vary widely depending upon the compliance path chosen, and suggest that almost no homes in Massachusetts are built to the basic prescriptive path in the building energy code. Significant improvements in building energy performance are needed to demonstrate full compliance with the energy code. However, the sample of ENERGY STAR homes shows that 100% performance-based compliance is a readily achievable target.

The underlying hypothesis of DOER is that the residential construction industry is increasingly comfortable with, and electing to follow performance-based trade-offs ranging from the REScheck enabled overall UA approach to full software modeling to create a HERS index rating or overall energy cost calculation for the home. DOER is supportive of this direction in the construction industry where it can demonstrate higher levels of energy performance and thus energy savings for homeowners, and believes that the building energy code should increasingly support whole-house performance-based approaches to compliance.

[1] UA = U-factor times area.

Comments and Analysis

All Home Energy Rating System (HERS) raters were asked to provide feedback on how long it took to complete the checklist, how many on-site visits they thought would be required if the checklist was completed during construction, and how practical they thought the checklist approach would be to assess compliance.

The entire checklist was filled out for each home at one time, as both the non-Energy STAR and the ENERGY STAR samples were assessed post occupancy. Completing the checklist post occupancy means many of the checklist items were not observable. The checklists for the ENERGY STAR homes were completed by the same HERS raters who inspected the homes at various construction stages as part of the ENERGY STAR-certification process, which greatly enhanced their ability to fully complete the checklist. However, not all of the items on the checklist are required for ENERGY STAR certification or conducting a HERS rating, so several items were not observed by the raters, and this likely affected the checklist results.

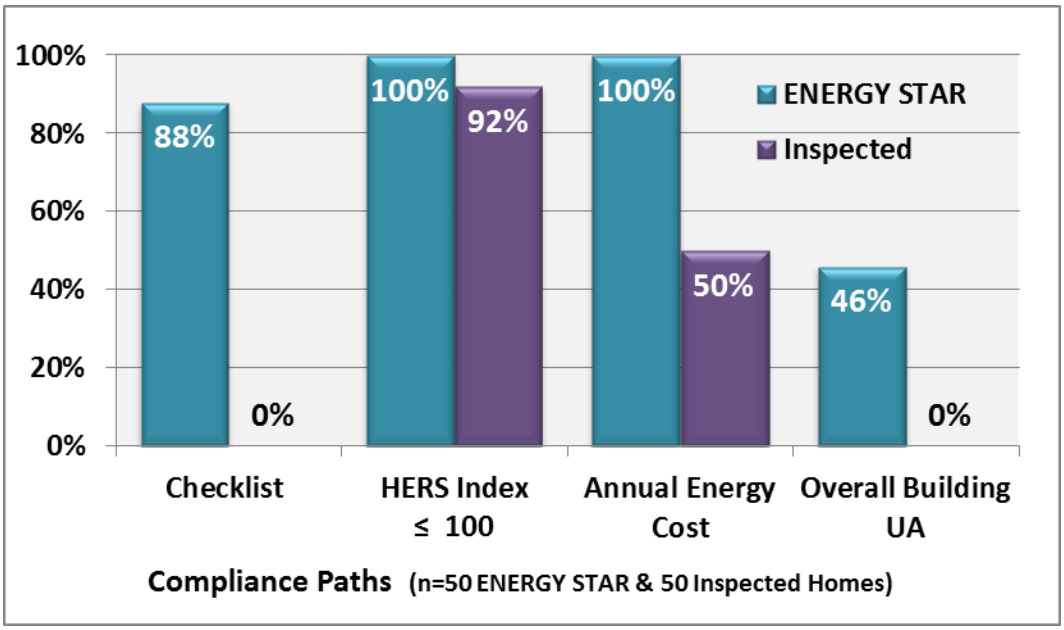
Compliance Rates

For both samples of homes, compliance was lowest under the Overall Building UA path with its limited scope for trade-offs under REScheck. In contrast, compliance was higher for the more performance-based compliance paths which allow for more flexibility and trade-offs, facilitating looking at the whole house as a system when making construction decisions and equally when assessing energy code compliance.

Table 1 shows the percentage of homes in the non-ENERGY STAR and ENERGY STAR samples that passed under different compliance paths. As shown, almost all (92%) of the non-ENERGY STAR homes complied under the Home Energy Rating (HERS Index $\leq$ 100) path[2], but only half (50%) passed under the Annual Energy Cost path; none of the non-ENERGY STAR homes complied under the checklist or Overall Building UA approaches. All ENERGY STAR homes passed the Home Energy Rating and Annual Energy Cost compliance requirements, and most (88%) passed using the checklist approach.

[2] It should be noted, that HERS 100 is typically a weaker code standard than a prescriptively built IECC2006 home, and the MA energy code has since been modified to reflect this. The updated MA 8th edition (IECC2009) residential code requires a HERS index of 75 or lower.

Table 1: Compliance Rates under Different Compliance Paths



It is important to note that a major reason for the difference between the compliance rates for the inspected non-ENERGY STAR and the ENERGY STAR homes using the checklist is that the two samples of homes were assumed to have originally complied with code under different compliance paths. When completing the checklists, the performance compliance approach was checked for all ENERGY STAR homes, because they all had certified HERS ratings, and the prescriptive compliance approach for all non-ENERGY STAR homes, because the original path under which these homes complied was unknown. This is consistent with PNNL's instructions for completing the checklist. The reason this difference is important is that when a home complies under a performance compliance path that allows trade-offs, such as the Home Energy Rating path in Massachusetts, specific items on the checklist do not have to meet prescriptive code requirement values to comply with code. If the checklists for the non-ENERGY STAR homes with HERS indices of 100 or lower (92% of non-ENERGY STAR homes) had been completed assuming the home originally complied using a performance compliance path, many of these homes would have likely complied under the checklist approach.

Feedback on Checklist

Completing the Checklist

It took some time for raters to understand several of the items on the checklist, but after reading the directions and asking questions they soon became more comfortable with it. If the checklist were being completed by people with responsibility for verifying code compliance they would likely have been trained about what to look for and how to respond to whether or not each item complies with code. That is a completely different situation from asking someone who is not directly involved with code compliance, and has not received training on how to complete the

checklist, to fill out the checklist based on available information from a post-occupancy, on-site inspection or prior HERS rating.

Practicality for verifying code Compliance

Raters say that, as a post construction code verification tool, the checklist is not practical due to a significant number of items being unobservable. As a code verification tool to be used during construction, they think it would do a good job of verifying code compliance, but to use it as intended would require multiple site-visits, and that code officials may find this more difficult than a HERS rater working on the project.

NMR team members who analyzed the compliance rates under multiple compliance paths think one of the key advantages to using the checklist to verify code compliance for a large number of homes is that the checklist is designed to be used for any home, regardless of what path the homes actually complied under—prescriptive, trade-off or performance. The instructions for completing the checklist provide clear directions, including an example, of how to complete the checklist for a home that complied under a trade-off or performance compliance path.

A potential limitation is that a home can "comply" using the checklist when only a few items on the checklist are observed. The checklist works on a point system—each checklist item is worth a specific number of points. If an item is compliant, the house receives the total possible points for that item; conversely if an item is not compliant the house does not receive any points. If the sum of the points received divided by the sum of points possible is 90% or higher the house "complies." The checklist accounts for the fact that not all items are applicable to all homes by allowing raters to specify an item as "N/A" or "Not Observable." When "N/A" or "Not Observable" is checked, the possible points and the points received for that item both default to zero, essentially removing that item from the compliance analysis.

1 Introduction

This report presents the findings from evaluating two sets of homes—50 non-ENERGY STAR-qualified homes and 50 ENERGY STAR qualified homes built at the end of the 2006 IECC code cycle in Massachusetts. In addition, this report discusses feedback HERS raters provided on using the checklist, barriers to code compliance and ideas for improving code compliance.

DOER was awarded funds from the American Recovery and Reinvestment Act (ARRA) via a contract between DOER and Northeast Energy Efficiency Partnerships (NEEP), which is funded via a separate contract between NEEP and the Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL), to analyze the effectiveness of building energy codes in Massachusetts. DOER used these funds to field-test various tools for evaluating code compliance (i.e., a code compliance checklist and an evaluation methodology) developed by PNNL, and to compare compliance (evaluated using the checklist) vs. energy performance (determined using HERS ratings) in the Massachusetts residential sector. Results from this pilot study ("pilot") will be used to provide feedback, ultimately to DOE, on PNNL's checklist and evaluation methodology, and on performance-based assessment vs. compliance-based assessment. DOER deliberately chose to use this study as an opportunity to compare a checklist based compliance approach – as proposed by PNNL - to more directly performance-based assessments of residential construction. The underlying hypothesis of DOER is that the residential construction industry is increasingly comfortable with, and electing to follow performance based trade-offs ranging from a REScheck enabled overall UA approach to full software modeling to create a HERS index rating or annual energy cost calculation for the home. DOER is supportive of this direction in the construction industry where it can demonstrate higher levels of energy performance and thus energy savings for homeowners, and believes that the building energy code should increasingly support whole-house performance-based approaches.

1.1 Non-ENERGY STAR-Qualified Homes Built To the IECC 2006

NMR and KEMA raters conducted on-site audits at 50 recently-completed non-ENERGY STAR-qualified homes built to the 2006 IECC. The raters evaluated these homes in two ways:

- By using the 2006 checklist developed by PNNL (in the form of an Excel file) to the extent practicable, given that the homes were completed and the audits conducted post occupancy
- By using REM/Rate software to provide HERS ratings, 2006 IECC Overall Building UA Compliance, and 2006 IECC Annual Energy Cost Compliance for each home

For each home evaluated the following files have been provided to DOER:

- Excel file of the completed checklist
- REM/Rate file

- REM/Rate 2006 IECC Overall Building UA Compliance Report
- REM/Rate 2006 IECC Annual Energy Cost Compliance Report

1.2 ENERGY STAR-Qualified Homes Built To the IECC 2006

HERS raters who originally conducted the ratings for a random sample of 50 ENERGY STAR-qualified homes that participated in the 2010 Massachusetts New Homes with ENERGY STAR Program completed checklists for these homes based on information they collected during the process of rating the homes. The HERS raters did not revisit the homes.

For each ENERGY STAR-qualified home evaluated the following files have been provided to DOER:

- Excel file of the completed checklist
- REM/Rate file
- REM/Rate 2006 IECC Overall Building UA Compliance Report
- REM/Rate 2006 IECC Annual Energy Cost Compliance Report

2 Feedback on Checklist

Raters who completed the checklist for 50 non-ENERGY STAR homes completed at the end of the IECC 2006 code cycle and raters who completed the checklist for a random sample of 50 ENERGY STAR homes that were certified in 2010 were asked the following five questions:

1. How long did it take you to complete the checklist?
2. How many visits to a home do you think it would require and how much time do you think a HERS rater or building inspector would need to spend on the checklist if it was being completed during construction?
3. Do you think any parts of the checklist are not practical and, if so, can you suggest improvements?
4. Do you feel adequately trained and prepared to complete the checklist or are there areas where you would recommend additional training and/or instructions?
5. Is there anything about the checklist that you found unclear or that did not make sense to you?

In total, 25 raters completed checklists and 13 responded to the above questions. Of the 13 raters who responded, 8 are NMR or KEMA raters who conducted post occupancy inspections of homes completed at the end of the 2006 IECC code cycle and 5 are raters who certified homes in the 2010 Massachusetts New Homes with ENERGY STAR Program. The five raters who certified ENERGY STAR homes in 2010 represent five different HERS rating companies.

One key difference between the ENERGY STAR and non-ENERGY STAR home checklists is that the performance compliance approach was checked for all ENERGY STAR homes and the prescriptive compliance approach for all non-ENERGY STAR homes. This is consistent with the instructions for completing the checklist provided on the Department of Energy (DOE) Building Energy Codes Program (BECP) web site.[3] The reason this difference is important is that when a home complies under a performance compliance path that allows trade-offs, such as the Home Energy Rating path in Massachusetts, specific items on the checklist do not have to meet prescriptive code requirement values to comply with code. As described on the first page of the instructions for filling out the checklist:

> *"The Code Value column on the checklist contains the prescriptive requirement which must be met under the prescriptive approach. If a trade-off or performance approach is used to demonstrate compliance, the buildings may NOT comply with these prescriptive values and yet may still be deemed to comply with the code (and therefore should be marked as compliant for the given checklist item) on the basis that some*

[3] Compliance with the energy code can be demonstrated by the prescriptive, trade-off, or performance approach. In evaluating building compliance, the prescriptive approach should be assumed unless documentation is obtained from the building department or responsible authority demonstrating compliance with either the trade-off or performance approach. Source: page 1 of the residential construction checklist instructions found at: http://www.energycodes.gov/arra/compliance_checklists.stm

other aspect of the building exceeds the code. For example, assume a trade-off approach was used and a valid worksheet or software report was submitted showing a compliant building in Climate Zone 3 with R-3 basement insulation. In Climate Zone 3, the code's prescriptive insulation R-value requirement for a basement wall is listed as R-5. In this example, the basement insulation should be marked as compliant even though it does not meet the prescriptive requirement given on the checklist."

2.1 Rater Feedback

Time required for completing the checklist: Raters say it took them from 15 to 60 minutes to fill out the checklist depending on the complexity of the home. When taking into account the time required to measure the conditioned floor area, which for this study had previously been done for use in REM/Rate, a completed checklist might take between one and four hours. Most of the raters who inspected non-ENERGY STAR homes filled out the checklist after filling out the data collection form that was used to collect information on site. Information on the data collection form was then transferred to the checklist. Raters who completed the checklist for ENERGY STAR homes relied on information collected for running REM/Rate to calculate the home's HERS index and notes from inspections conducted during construction.

Number of visits and time required to complete checklist during construction: Most raters say they think three site visits would be necessary to complete the checklist during construction; this is in addition to acquiring building plans. The first visit would verify if slab/foundation insulation was installed. The second visit would occur during the installation of insulation in the walls, frame floor, and ceiling to verify R-values, quality of insulation installation and air sealing, and to look for labels on windows and doors showing efficiency and air leakage information. The final visit should be scheduled post construction to verify envelope leakage. Between one to two hours of on-site time should be allotted per visit, totaling three to six hours of time, to complete the checklist during construction.

Practicality of the checklist and suggestions for improvement: Raters say that, as a post construction code verification tool, the checklist is not practical due to a significant number of items being unobservable. As a code verification tool to be used during construction, they think it would do a good job of verifying code compliance. However, without a reference manual/plans there are certain checkboxes, such as verifying that insulation is being installed to manufacturer specifications and heating and equipment type and capacity are as planned, that will be hard or impossible to verify from a site visit alone.

General suggestions for improving the form include:

- There are instances where footnotes should be given greater priority so that they do not get overlooked. Examples are the footnote for frame floor insulation suggesting that R-19 is sufficient if it fills the cavity and the footnote for ceiling insulation saying that R-30 is sufficient if the insulation is not compressed in the eaves. These footnotes are easily glossed over given the current checklist format.

- Raters who inspected non-ENERGY STAR homes suggest that some items could possibly be removed from the form: certificate posted checkbox (not present at any site visited), the damper checklist (present at almost all sites visited), and the circulating hot water checkboxes (not present at any site visited).

Training needed to complete the checklist: Raters say that the training required to become a HERS rater is sufficient to fill out the checklist properly. Additional clarification on items not frequently seen in homes, such as circulating hot water service systems, would be helpful.

Checklist items unclear or confusing: Raters identified several areas where the checklist items or instructions could be further clarified to speed up the process and lower potential errors caused by confusion. In addition, the areas of confusion listed below include questions that raters of ENERGY STAR homes raised while filling out the checklist; in some cases these questions were referred directly to PNNL for clarification.

- List out approved duct sealing methods.
- Provide basic definitions for manufacturer specification on typical floor, wall, and ceiling insulation types to help standardize responses.
- The wording for glazed fenestration and swinging door air leakage suggests you should test/measure the leakage; it is not clear until you read the detailed instructions that it is asking for information that can be found on labels, or looked up if you know the manufacturer and model number, and that these requirements do not apply to site-built windows and doors.
- More detailed definitions of sunroom and mass wall would leave less room for confusion about how to complete these fields and improve consistency.
- Regarding recessed lights, spelling out what the code is would circumvent having to look up the code and cut down on time in the field.
- Insulation quality can vary from one section of a house to the next. While one area of an attic might meet code, there can be another section that does not. The current checklist does not account for variations in insulation qualities. Adding additional cells would solve this issue.
- Raters had different views on how the air sealing items should be filled out. Some raters felt comfortable saying air sealing requirements were met if they did not visually inspect every item, but blower door testing showed low envelope leakage; other raters checked that the air sealing items complied only if they visually inspected them. (This issue has been addressed in the 2009 checklist by asking for blower door testing results and if ACH50[4] is ≤ 7 instructing whoever is filling out the form to mark the items addressing visual inspections of airs sealing N/A.)

[4] Air changes per hour at 50 Pascals.

- Raters were confused about how to fill out items that were listed as N/A (not applicable) in the prescriptive code value field. A call to PNNL verified that any item with N/A in the "Code Value" field should also be N/A in the "Complies" field.
- If all ducts were in conditioned space, raters questioned whether the response for duct insulation should be N/A because the checklist asks for the insulation R-value of ducts in unconditioned space or should be complies because the ducts comply with code requirements for ducts installed in conditioned space. PNNL verified that duct insulation should be checked as complying if all ducts are in conditioned space.
- Raters responded inconsistently to the item addressing HVAC piping insulation. If a home did not have a boiler but had central air conditioning some checked HVAC piping insulation N/A and others responded complies, or does not comply, based on whether or not the refrigerant lines for the air conditioning system were insulated. PNNL verified that HVAC piping in cases where there is a central air conditioning system or split system heat pump refers to the refrigerant piping.
- Raters wanted clarification on whether or not the items addressing circulating hot-water piping insulation and controls applied only to systems that pump hot water through the hot water piping so that obtaining hot water at the faucet is nearly instantaneous. PNNL verified that these items applied only to this type of recirculating pump system.
- Raters of the ENERGY STAR homes, where the homes were assumed to follow the performance compliance path were confused about when to say an item complied or did not comply with code.

Several of the questions raised by raters are clearly addressed in the instructions. However, it is sometimes hard to convince people to read through several pages of instructions. If the checklist were being completed by people with responsibility for verifying code compliance they would likely have been trained about what to look for and how to respond to whether or not each item complies with code. That is a completely different situation from asking someone who is not directly involved with code compliance to fill out the checklist based on available information from a HERS rating done earlier.

One final comment is that for anyone reviewing completed checklists it would be helpful to have the type of HVAC equipment installed listed, in particular to identify whether or not systems are ducted, to know if the checklist items related to ducts and HVAC piping should be checked as complying or not complying with code or N/A.

3 Code Compliance—Barrier and Ideas for Improving

Six HERS raters commented on barriers to code compliance and ideas for improving compliance.

- *"I think it is much easier for a HERS Rater to complete the checklist than for a Building Inspector. For example, Building Inspectors have been looking at insulation for years to see that it is there without regard to whether it is working and with very little concern for thermal by pass issues. Similarly with HVAC ducts, a nicely wrapped duct system constitutes code compliance with no regard for or ability to test the tightness. Allowing HVAC contractors or building contractors to inspect/verify and/or test their own systems isn't the answer either—for obvious reasons."*
- *"I'd approach this with a philosophy of cost efficacy, understanding and calculating (at least a decent estimate of) the 'value proposition' for each proposed enforcement item. I'd do this using the important metrics (energy use, fuel cost, CO2 production, etc.), using EIA fuel cost projections (I've done this for a variety of wall assemblies, the results are interesting) over the expected lifetime of each measure. Net Present Value calculations are often used for such things, I think this could be a good application. Then, do some creative thinking about how best each item can be verified, with value of verification and cost to verify in hand.*

  I think that as the 'performance path' for energy code compliance is more widely adopted and used, the HERS Rater as a mechanism to supplement the regular building code inspection process is something to be considered. HERS Raters have Quality Assurance done to their work by their Provider, and often by Programs (e.g. Massachusetts New Homes with ENERGY STAR). They are often on-site for program-related inspections, are typically well educated in verification, and are more often than not highly motivated to do a good job, recognizing the realities of construction.

  I think it is critical that each requirement have a well thought out 'explanation' that will resonate with the builder. Builder 'buy in' is key to reducing compliance issues, credibility here can work wonders; lack of credibility and comprehension of 'the reason' can create real issues and can dis-engage builders' enthusiasm. And, have some numbers like "... impact varies, but air infiltration can be 25% to 30% of home heating loss and for a typical home this can be $xxx of additional gas per year."

  Finally, I think incentives (carrots) are a much better approach than building code minimums, because they can engage the enthusiasm of the builders, people who generally take pride in their work and their product. A tiered structure can provide a 'next level to which to aspire'. Well-designed incentives can be very productive. Metrics like HERS indices can give bragging rights."
- *"One idea would be on the job training for code officials. If code officials don't fully understand the energy code it is difficult for them to enforce. I think a combination of classroom training and on the job training would be helpful."*

- *"We think the barriers to code compliance are poor planning, lack of knowledge. Although some builders will say cost is a barrier, the ones who do it right are often not paying any more to build. The solution is education and more and better inspections by building officials and 3rd party entities. The trainings sponsored by the DOER go a long way to help educate builders and code officials."*
- *"If anything, I think there are fewer barriers to meeting code for builders in the program [Massachusetts New Homes with ENERGY STAR] because the HERS rater acts as an advisor to the builder* to *meet code as well as the requirements for the Program. It's another set of eyes looking at things. And since the HERS raters generally don't know what individual building inspectors enforce and don't enforce, they play it safe."*
- *"We most importantly need consistent and strict enforcement. This can only be reasonably implemented by reducing the complication of the code verification process; and I mean both complication in the code itself and complication in the building department processes. Simpler rules will help get more consistent enforcement and so I would also suggest air sealing requirements not be so prescriptive (I think we still need to emphasize the cold side of any thermal boundary should not be a vapor barrier and should not be sealed dramatically tighter than the warm side), but instead rely heavily on a very aggressive air leakage limit (less than 2 or 3 ach50) verified with a final test by a qualified professional. And, perhaps we need to make it more clear that we can shift the responsibility for the energy code enforcement from the building departments to professionals such as HER raters—akin to the way engineers are given certain responsibilities."*

4 Sampling Methodology

The sampling methodology involved developing a sample of new homes from utility new residential permanent service requests and the selection of homes for the on-site inspections based on their location and whether they were spec or custom built.

4.1 Sample Development

The sample of homes for the on-site inspections was developed from new residential permanent service requests collected by the four investor owned electric utilities in Massachusetts: National Grid, NSTAR, Unitil, and Western Massachusetts Electric. New permanent service requests have been used as an unbiased way to identify newly constructed homes in Massachusetts over the past several years for baseline studies and new home buyer surveys. However, new service requests may also involve additions to existing homes and other major renovations which must be screened out in scheduling the on-site inspections.

4.1.1 Data Cleaning

The sample for the on-site inspections was drawn from permanent new service requests received by the utilities from October 1, 2009 through June 30, 2010. These dates were chosen to target homes built at the end of the IECC 2006 code cycle in Massachusetts; building permits drawn starting on July 1, 2010 had to come under the IECC 2009 building code. The new service requests were cleaned to remove addresses where:

- The home had participated in the Massachusetts ENERGY STAR for New Homes Program.
- The housing unit was obviously part of a building with five or more units.
- There was only the builder's name on the utility record.

After eliminating the above addresses, there were 1,924 possible addresses to be considered for the on-site inspections. The majority of these could be assumed not to involve new construction and would ordinarily be screened out when customers were called to set up appointments for the inspections. However, since building permits drawn between January 1 and June 30, 2010 could be under either IECC 2006 or IECC 2009, it was necessary to check each possible new home address through the local building department to ensure that the home was built under IECC 2006; the checks with the building departments also meant that new service requests that did not involve new home construction could be screened out at this stage.

4.1.2 Building Department Data Collection

The possible new homes identified by the new service requests covered 169 cities and towns across Massachusetts; local building departments were contacted to verify the homes were built under IECC 2006. Table 4-1 presents the method used to gather the required information from the local building departments. Only about one in five municipalities had all the information

needed available on-line, the easiest and most cost-effective option. Close to two-thirds required at least one phone call to look up the necessary data. Even more expensive and time-consuming were the in-person visits required by 21 municipalities. Four municipalities required payments from $15 to $39 for providing the needed data either over the phone or in person. Finally, the study was unable to gather data from 12 municipalities despite multiple attempts.

Table 4-1: How Required Information Was Obtained from Local Building Departments

Method	Number of Municipalities	Percent
Telephone call	104	62%
Data available on-line	33	20%
In-person visit	21	12%
Data not provided	12	7%
Total	169	100%

After all available building department data had been checked, there were 592 names and addresses representing occupied homes in one to four unit buildings that were built under IECC 2006 and did not participate in the Massachusetts ENERGY STAR for New Homes Program. Each homeowner was mailed a letter, with the DOER and Program Sponsors' logos, explaining the purpose of the study, what the on-site inspections would be like, and the incentives of $150 to $200 offered for participation.

4.2 Sample Selection

The study considered the use of the Department of Energy's (DOE's) Building Energy Codes Program (BECP) State Sample Generator, a tool that generates the number of randomly sampled new homes to take from each county in the state based on an average of three previous years of construction data. However, in Massachusetts there were additional factors important in the generation of the sample that are not considered by the State Sample Generator, namely, the number of homes in communities that have since adopted the IECC 2009 stretch code and the split between spec and custom built homes. These factors are included in the sampling plan for the ongoing Massachusetts baseline study of 100 homes built under the IECC 2009 building code. It was decided to use the same sampling plan for the DOER Code Pilot study and simply cut the sample in half since the goals was to complete 50 rather than 100 on-site inspections.

Table 4-2 presents the sampling plan, which is based on the number of building permits for homes in one to four unit residential buildings issued in stretch code and non-stretch code communities in each county in 2010.

Table 4-2: Sampling Plan

County	Total On-Site Inspections	On-Site Inspections in Non-Stretch Code Communities	On-Site Inspections in Stretch Code Communities
Barnstable	3	3	0
Berkshire	1	1	0
Bristol	4	4	0
Dukes	1	1	0
Essex	4	3	1
Franklin	1	1	0
Hampden	3	2	1
Hampshire	2	2	0
Middlesex	11	7	4
Nantucket	0	0	0
Norfolk	4	4	0
Plymouth	5	4	1
Suffolk	1	0	1
Worcester	10	8	2
Total	50	40	10

In addition to the specified number of on-site inspections by county and stretch/non-stretch code community, the study attempted to maintain a mix of 74% spec and 26% custom built homes. This split reflects the spec/custom split in one to four unit buildings that participate in the Massachusetts New Homes with ENERGY STAR Program. Spec and custom built homes were defined according to the homeowner's response to the following screening question:

How did you purchase your home? [Read Responses]

1. Purchased land and worked with an architect and/or builder to build the home
2. Had a house plan and a lot and hired a contractor/builder to build the home
3. Purchased a lot from a builder selected one of several house plans offered by the builder and selected from various available upgrade options
4. Purchased a home that was under construction and selected from various available upgrade options
5. Purchased a finished home
6. I am the owner and builder

Homes were classified as custom built if the homeowner chose responses 1, 2, or 6; if the home owner chose responses 3, 4, or 5, the home was classified as spec built.

There was also a goal to perform no more than one on-site inspection in each community; the reasoning is that new residential construction in each city and town would come under the same building inspection department and may thus have similar rates of code compliance.

4.2.1 Recruitment

As noted above, the data cleaning and ascertaining the applicable code with the local building departments resulted in a starting sample of 592 names and addresses from which to recruit the 50 on-site inspections. However, the requirements for one inspection per community and the spec/custom mix meant that some of this sample could not be used. Of the 592 names, 161 were never called because the quota of inspections in a particular county was reached. Additionally, once an inspection was completed, every other contact in that community was considered not eligible; this accounted for an additional 194 names, leaving a valid sample of 237 names. Table 4-3 summarizes the disposition of the sample.

Table 4-3: Sample Disposition

Sample Description	Number	Percent
Starting Sample	592	
Never Called	161	
Sample Used	431	
Sample considered not eligible	194	
Valid Sample	237	
Completed on-site inspections	50	21%
Refusals	36	15%
Not reached	151	64%

It is important to note that the overwhelming majority of the valid sample not reached consists of messages left for homeowners that had no follow-up because the desired number of on-site inspections was reached. Only a small number, 24, had wrong or disconnected numbers and only 2 had language barriers. Of the homeowners who were reached, there were more acceptances (50) than refusals (36). This is a very encouraging acceptance rate for a study where the homeowner has to be present and provide access to all parts of the home for two to four hours. The recruiter reported that many respondents were particularly interested in the verbal feedback about their new homes' energy efficiency that they would be getting as part of this study; she believes the high acceptance rate is most attributable to this factor.

4.2.2 Completed On-Site Inspections

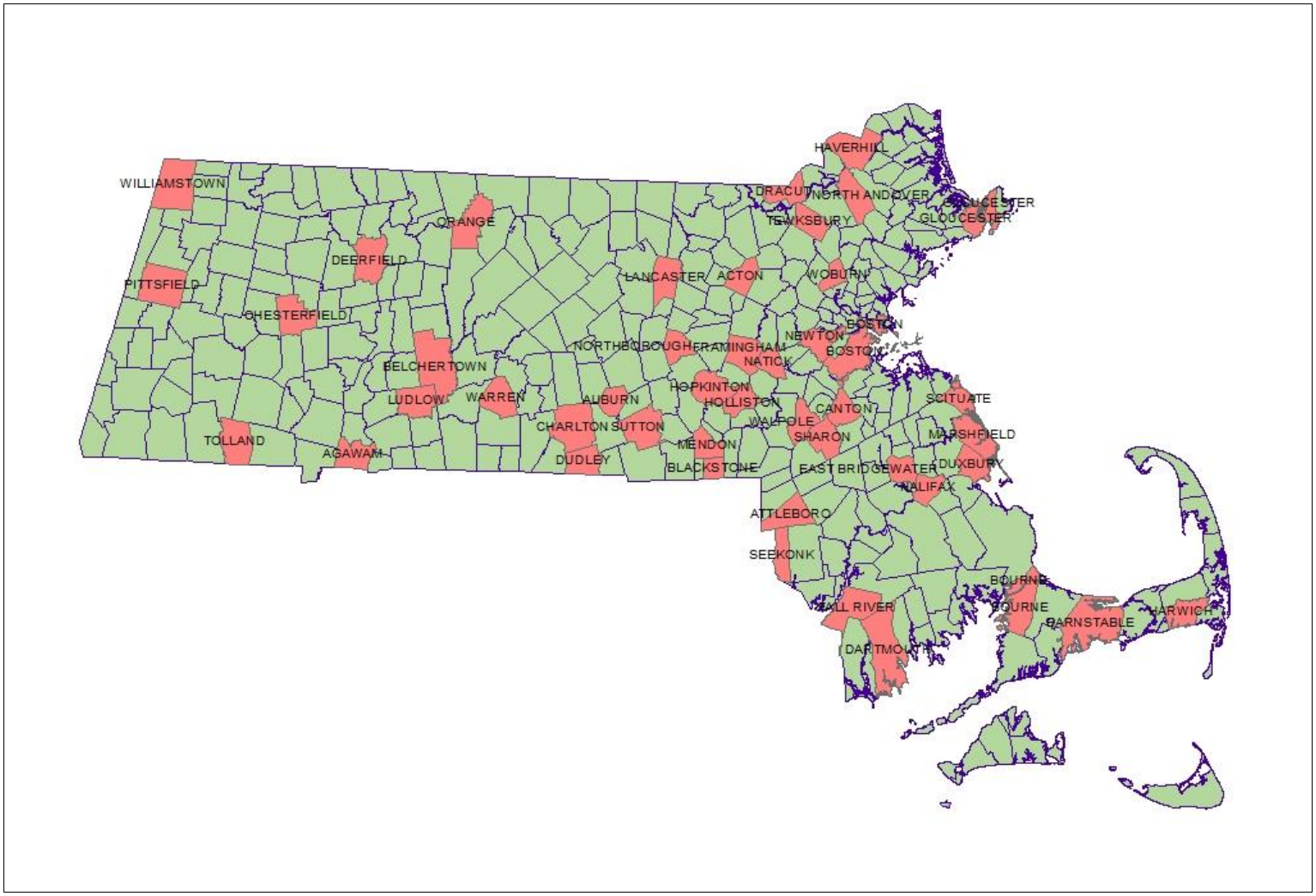
As Table 4-4 shows, the completed on-site inspections followed the sampling plan shown in Table 4-2 and the desired spec/custom mix fairly closely. The study has a mix of 76% spec built and 26% custom built homes. Two-thirds (66%) of the on-site inspections took place in non-stretch code communities and 34% took place in stretch code communities.

Table 4-4: Completed On-Site Inspections

County	Total On-Site Inspections	Non-Stretch Code	Stretch Code	Spec Built	Custom Built
Barnstable	3	3	0	2	1
Berkshire	2	0	2	0	2
Bristol	5	5	0	5	0
Dukes	0	0	0	0	0
Essex	3	2	1	1	2
Franklin	2	1	1	1	1
Hampden	3	3	0	3	0
Hampshire	2	0	2	1	1
Middlesex	9	3	6	9	0
Nantucket	0	0	0	0	0
Norfolk	4	4	0	4	0
Plymouth	6	5	1	3	3
Suffolk	1	0	1	1	0
Worcester	10	7	3	8	2
Total	**50**	**33**	**17**	**38**	**12**

Moreover, the inspections took place in 47 cities and towns across Massachusetts; there was only one inspection done in 44 communities and two inspections done in each of three communities. The 47 communities covered are shown in Figure 4-1.

Figure 4-1: On-Site Inspections



5 On-site Inspections

Between April and June of 2011, NMR and KEMA raters conducted 50 site visits at homes across Massachusetts. All 50 inspections were conducted at homes permitted under the 2006 IECC. As part of the inspections we collected data with two primary tasks in mind:

1) Conducting a full HERS rating using the REM/Rate software
2) Filling out the 2006 IECC checklist developed by PNNL

5.1 Data Collection Form

An on-site data collection form that contained the inputs required to conduct a full HERS rating and fill out the 2006 IECC checklist was developed. There was a significant amount of overlap between the information required for a HERS rating and the information required for the checklist. The data collection form was broken up into six primary sections that are detailed in Table 5-1. The code checklist section of the form identified inputs that were needed to populate the checklist, but were not needed for REM/Rate. All other sections of the data collection form indicate areas of overlap between the checklist and REM/Rate, or they are indicative of data that are specifically required for HERS ratings.

Table 5-1: Data Collection Form Inputs

General Information	Insulation/Shell Measures	Mechanical Equipment	Test Results	Lighting & Appliances	Code Checklist
• House type • Area of conditioned space • Volume of conditioned space • Primary heating fuel • Stories • Bedrooms • Thermostat type • Builder type • Own/Rent • Evaluation region	• Exterior walls • Ceilings • Frame floors • Rim/Band joists • Windows • Skylights • Doors • Slab Floors • Foundation walls • Mass walls • Sunspaces	• Heating equipment • Water heating equipment • Cooling equipment • Duct insulation • Renewables	• Blower door results • Duct blaster results	• CFL fixtures • Incandescent or Halogen fixtures • Fluorescent tube fixtures • LED fixtures • Ceiling Fans • Refrigerators • Dishwashers	• HVAC piping insulation • Recessed fixtures • Damper openings • Certificate • Heat pump thermostat • Circulating hot water • Air sealing

5.2 BECP Materials—2006 Checklist and Instructions

The 2006 IECC checklist for region 5 and instructions for completing the 2009 IECC checklists were available on the BECP web site. We converted the 2006 IECC checklist to Microsoft Excel

format to facilitate analysis and edited the instructions for completing the 2009 IECC checklist to be consistent with the 2006 IECC checklist. The 2006 IECC checklist is essentially a trimmed down version of the 2009 checklist—it accounts for differing required values between the codes and does not address items unique to the 2009 IECC (Table 5-2).

Table 5-2: 2009 Checklist Items Not Included in 2006 Checklist

Inspection Stage	Checklist Item
Foundation Inspection	Snow melt controls
Framing/Rough-In Inspection	Duct tightness via rough-in test
Insulation Inspection	Air sealing complies via blower door test
Final Inspection	Attic access insulation
Final Inspection	Duct tightness via post-construction test
Final Inspection	Lighting-50% high efficacy lamps
Final Inspection	Wood burning fireplace gasketed, outdoor air supply
Final Inspection	Programmable thermostats on force air furnaces
Final Inspection	Pool heaters, covers, controls

As the instructions state, "the checklist is divided into stages corresponding to traditional building inspection stages." These stages consist of the following: pre-inspection/plan review, foundation inspection, framing/rough-in inspection, insulation inspection, and final inspection. The beginning of the instructions provide guidance on how to fill out the checklist, depending on the compliance path chosen, before diving into a detailed description of each checklist item and the proper way to complete the checklist for said item. In the next section we discuss our experience with each stage of the checklist, how the items within each stage work from a post occupancy compliance perspective, and how our methods deviated from the PNNL instructions.

5.3 Limitations Completing the Checklist Post Occupancy

The BECP guidelines, in other words the checklist instructions, were developed assuming code officials and/or HERS raters would be visiting sites on numerous occasions during construction. Our study was focused on assessing energy code compliance from one visit to an occupied home. Due to the differences between the energy code assessment methodologies of the BECP guidelines and our study (multiple visits vs. one visit) there were bound to be differences in both scope and approach. This section discusses these differences along with the limitations of the checklist in a post occupancy compliance study.

5.3.1 Pre-Inspection/Plan Review

The NMR and KEMA raters did not attempt to obtain building plans, from building departments, for the 50 sites visited, and as such deviated from the guidelines for the "Pre-Inspection/Plan

Review" stage of the checklist.[5] This portion of the guidelines instructs inspectors/raters to determine whether or not plans are available at the building department, and whether or not these plans document compliance with 2006 IECC. This section of the guidelines also asks raters to confirm that proper HVAC load calculations were conducted prior to installation. While we did not attempt to obtain plans from building departments, we did ask all homeowners whether or not plans were available on site, and we successfully obtained plans for ten homes, two of which sufficiently demonstrated compliance with 2006 IECC. We were unable to verify the accuracy of HVAC load calculations for any of the homes visited.

5.3.2 Foundation Inspection

The "Foundation Inspection" stage of the checklist is focused on the measurement and verification of slab insulation, exterior foundation wall insulation, crawl space insulation, and exterior insulation protection. The BECP guidelines instruct raters to inspect slab insulation prior to the pouring of the slab. Similarly, the guidelines instruct raters to inspect foundation and crawl space insulation prior to the foundation being backfilled. Due to the scope of our compliance evaluation we were unable to follow the guidelines instructions for this portion of the checklist. For slab insulation and interior crawl space insulation (in an enclosed crawl space), we were unable to verify whether or not insulation was visible at any of the 50 sites visited. Exterior foundation insulation was verifiable at two sites, but we were unable to verify the installation quality and the depth of the insulation.[6]

5.3.3 Framing/Rough-In Inspection

The "Framing/Rough-In Inspection" stage of the checklist focuses on the verification of a number of items, many of which were unverifiable when assessing compliance in an occupied home. Items that were typically unverifiable are listed below:

- Door, glazing, and skylight U-factors
- Glazing and skylight SHGC values
- Mass wall insulation values[7]
- Duct sealing
- Building cavities used as supply ducts
- IC-rate recessed lighting fixtures
- Fenestration and swinging door air leakage

U-factors, SHGC values, and air leakage values are typically found on an NFRC stickers located on windows and doors immediately after installation. These stickers are often removed as soon as a home is occupied, and as such these measures were unverifiable during our site visits. The BECP guidelines suggest recording the manufacturer, make, and model of glazing and doors

[5] The budget did not include hours for collecting building plans from the permitting building departments.
[6] When exterior foundation insulation was verified we were able to estimate the R-value based on the thickness of the insulation material.
[7] It should be noted that we did not observe any mass walls during our site visits.

when the NFRC sticker is not available on site. This information was often unobservable on site and led to deviations from the guidelines for these items; default values from the REM/Rate software were assumed.

Duct sealing was almost always unobservable as insulation was covering the ducts more often than not, preventing visual verification of duct sealing. Similarly, we were often unable to verify that building cavities were not used as supply ducts, as most building cavities are enclosed once construction is complete. Finally, the air leakage characteristics of recessed fixtures were difficult to determine post occupancy without disturbing attic insulation, and were often not observed during the site visits.[8]

While many of the checklist items in this stage were unobservable we were able to identify a few of the items. The observable items included the following:

- Duct insulation
- HVAC piping insulation
- Circulating hot-water piping insulation[9]
- Outdoor intake/exhaust openings[10]

For the items just listed we were able to complete the checklist according to the BECP guidelines in almost all instances.

5.3.4 Insulation Inspection

The "Insulation Inspection" stage of the checklist was one of the easier stages of the checklist to complete. Many insulation measures were verifiable on site, and for those that were not easily verifiable it often seemed reasonable to make an educated assumption of what the insulation values were based on other characteristics (e.g. wall construction and stud depth). The following measures were filled out on almost all checklists:

- Floor insulation R-value
- Floor insulation installation
- Wall insulation R-value
- Basement wall interior insulation R-value
- Basement wall interior insulation depth

Floor insulation and installation was almost always verifiable as insulated frame floors are rarely enclosed. Wall insulation was frequently verifiable in the basement or attic knee walls, although the installation was sometimes reported as "not observable" because the walls were enclosed. When wall insulation was not verifiable we assumed an R-value based on the stud depth of the wall, which was determined either by looking at the width of a door frame or window, or by

[8] Recessed fixtures were sometimes inaccessible, particularly in attics with an enclosed floor.
[9] We did not see any circulating hot-water piping system during our site visits.
[10] The checklist instructions suggest identifying all openings. We were unable to verify openings on the upper floors, but assumed they were compliant if the lower floors were.

removing an electrical outlet cover and measuring the depth of the wall.[11] Interior basement wall insulation, in conditioned basements, was rarely verifiable due to enclosed walls, but we were able to assume an R-value based on stud depth.

As mentioned, when necessary we assumed an R-value for above grade wall insulation and basement wall insulation based on the stud depth of those walls. This represents a deviation from the BECP guidelines, which suggest these values need to be verified before interior finishes are installed.

The 2006 IECC checklist asks raters to visually verify air sealing for a number of different areas in the home. This was often not possible given the post occupancy nature of the study, and even when air sealing was visible it was only visible in small spaces that may not have represented the house as a whole. The 2009 IECC allows air sealing measures to be evaluated based on the number of air changes per hour in the home. This is determined based on the diagnostic results of a blower door test. Were this same method allowable under 2006 IECC we would have been able to complete the checklist for air sealing measures by reporting ACH50.

5.3.5 Final Inspection

We were able to complete the checklist for all of the items listed in the "Final Inspection" stage. These items included ceiling insulation R-value, ceiling insulation installation, heating and cooling equipment loads and capacity, the identification of a compliance certificate, the identification of a thermostat for heat pumps, and the verification of automatic controls for service water piping systems.[12] It should be noted that we did not come across many heat pumps, and we did not see any circulation hot water service systems.

5.4 Timing—Evaluating Occupied Homes for Compliance

As previously mentioned, this project had two primary tasks with regards to data collection:

1) Conduct a full HERS rating at each of the 50 sites visited
2) Fill out the 2006 IECC checklist developed by PNNL

Each of these tasks was met by visiting 50 occupied homes for a one-time evaluation of energy efficiency and code compliance. NMR and KEMA sent two raters to each home to conduct the on-site inspections and gather all of the necessary data to complete a HERS rating and fill out the checklist. These site visits typically lasted three to four hours and consisted of, among many other things, the verification of shell characteristics, the verification of HVAC equipment

[11] We assumed R-19 for 2x6 stud walls, and R-11 for 2x4 stud walls. These are common insulation values for these sized walls.

[12] While we were able to verify the heating and cooling equipment loads we were unable to verify that these loads matched those on the plans as we never saw any load calculations.

capacities and efficiencies, the verification of compliance with checklist items, and blower door and duct blaster diagnostic tests.[13]

After gathering the necessary data on site, one of the two raters who worked on site would complete the data collection form. In order to fully complete the data collection form a rater typically spent anywhere from 4 to 12 hours, depending on the size of the home, entering and analyzing the on-site data. Most of the analysis was done in the office, and it was required to complete a full HERS rating—it was not required to complete the checklist. In order to conduct a HERS rating, raters must calculate the areas for all of the important shell features of a home. These following calculations were responsible for a large portion of the office-based work load:

- Area of conditioned space
- Volume of conditioned space
- Above grade wall areas
- Foundation wall areas
- Glazing areas
- Frame floor areas
- Ceiling areas

Once the data collection form was completed the data were cleaned in order to fix any errors and maintain consistency across raters. This process typically took, on average, 45 minutes per site.

Once the data collection form was complete (and cleaned) filling out the checklist was fairly simple. Initially it took raters a little longer to fill out the checklist. Raters needed some time to familiarize themselves with the various checklist entries and instructions. Once raters got used to the checklist it typically took about 20 minutes to one hour to complete the checklist. The timing was dependent on the size and configuration of the home, as well as the number of points possibly attained using the checklist. The more points that were possible the longer it took to complete the checklist.

Similar to the checklist, completing a REM/Rate file and HERS rating was not very difficult once the data collection form was cleaned and filled out in its entirety. The data collection form was developed to be a near one-to-one match with REM/Rate. For this reason, filling out the REM/Rate files was largely a "plug and chug" operation. Typically it took one to three hours to complete a REM/Rate file, again depending on the size and complexity of the home.

[13] Time spent on site occasionally pushed five hours in some homes, and some tests had to be skipped to meet the homeowner's expectations of raters being on site for only four hours.

In total, we averaged between 16 and 17 hours of employee time to complete all of the required tasks for each site. This estimate does not account for project management, data collection form development, or travel. The break down for this estimate is below:

- Field work—Two raters at three and a half to four hours per site
- Data collection form—One rater at six hours per site
- Data cleaning—One rater/analyst at 45 minutes per site
- Checklist—One rater at 30 minutes per site
- REM/Rate—One rater at two hours per site

6 Checklists for ENERGY STAR Homes

HERS raters who certified ENERGY STAR homes in the 2010 Massachusetts New Homes with ENERGY STAR Program were asked to complete the 2006 IECC checklist based on information they collected during the process of rating the homes; they were not asked to revisit the homes. A random sample of 50 homes was developed and the raters who certified those homes provided completed 2006 IECC checklists and REM/Rate files for each home.

The sample of 50 homes was developed using a random number generator. There were 885 single-family homes (housing units in one to four unit buildings) in 344 projects certified in the 2010 program year. To avoid selecting multiple homes in one project, a random sample of 50 projects was developed. Next, for each selected project with more than one home a random number generator was used to select the home in that project to include in the sample. The final sample included homes certified by 15 HERS raters in 8 different HERS rating companies.

The HERS raters who completed the checklists were asked to provide feedback on using the checklists. Their feedback was consistent with the feedback from raters who conducted the on-site inspections of 50 non-ENERGY STAR homes completed at the end of the 2006 IECC code cycle and is covered in Section 2: Feedback on Checklist.

One key difference between the ENERGY STAR and non-ENERGY STAR home checklists is that the performance compliance approach was checked for all ENERGY STAR homes and the prescriptive compliance approach for all non-ENERGY STAR homes. This is consistent with the instructions for completing the checklist provided by the DOE. The reason this difference is important is that when a home complies under a performance compliance path that allows trade-offs, such as the Home Energy Rating path in Massachusetts, specific items on the checklist do not have to meet prescriptive code requirement values to comply with code. Initially, several of the raters of ENERGY STAR homes were confused about when to say an item complied or did not comply with code. The directions for completing the checklist include a very clear explanation, including an example, of how to complete the checklist for homes that comply with code via a trade-off or performance approach. After reading these directions raters understood the protocol for completing the checklist for homes following a performance compliance approach.

The expectation was that checklists completed by HERS raters who inspected homes during construction would have fewer “not observable” items and this is the case. However, not all the items on the checklist are needed to produce a HERS rating or for a home to meet ENERGY STAR standards. Items that were frequently checked as not observable include plans that demonstrate energy code compliance, HVAC load calculations, and verification that installed heating and cooling equipment type and capacity were as planned. The Massachusetts New Homes with ENERGY STAR Program requires Manual J calculations for cooling loads, but not heating loads; therefore the checklist items described above were checked as not observable in many cases.

7 Checklist Data

7.1 Compliance Paths

Code compliance was assessed using four different compliance paths. The four compliance paths are the checklist (prescriptive path), the Home Energy Rating path (performance), the Annual Energy Cost compliance path (performance), and the Overall Building UA path (trade-off).

7.1.1 Checklist—Prescriptive Compliance Path

Prescriptive path refers to a compliance path in which various aspects of a home are inspected individually to determine compliance. Under the prescriptive path items are typically assessed in one of two ways:

1) The item either meets or exceeds a minimum value provided for it (e.g. wall insulation R-value)
2) The item either is, or is not, compliant on a yes/no basis (e.g. wall insulation installation)

The prescriptive compliance path is essentially a compliance path using the 2006 IECC checklist. That is, a home complying under the prescriptive path was only deemed to be in compliance using the checklist if the home met or exceeded 90% of the prescriptive requirements for applicable items on the checklist.[14]

7.1.2 The Home Energy Rating Path (Performance)

In the amendments to the seventh edition of the Massachusetts building code, the Board of Building Regulations and Standards (BBRS) included the Home Energy Rating compliance path, which allowed builders to comply with the energy code if the home had a HERS rating conducted by a certified HERS rater and achieved a HERS index of 100 or fewer points.[15] HERS ratings are performed using REM/Rate software, where REM/Rate compares the "design" or "as-built" home to the "reference" home. The current reference home is based on the 2006 IECC. To calculate a HERS index, REM/Rate models the reference home to be almost identical to the as-built home (e.g. size, shape, orientation), with the only major differences being that the reference home is built to meet the 2006 IECC prescriptive requirements. A home built to the 2006 IECC prescriptive code requirement should score a HERS index of 100.[16]

7.1.3 Annual Energy Cost Compliance Path (Performance)

The Annual Energy Cost compliance path is very similar to the Home Energy Rating path for compliance, though there are some important differences. Similar to the Home Energy Rating path, the Annual Energy Cost compliance path is based on REM/Rate models and compares the

[14] The checklist allows for code officials or raters to specify "not observable" for any item. In these cases the home does not need to meet the prescriptive requirement to be considered compliant.
[15] http://www.mass.gov/Eeops/docs/dps/inf/780_cmr_61.00_energy_efficiency.pdf
[16] http://www.resnet.us/home-energy-ratings

as built home to the 2006 IECC reference home. The Annual Energy Cost compliance path differs from the Home Energy Rating path in that it only compares the as built and reference home for heating, cooling, and domestic hot water costs. This compliance path does not consider other factors that are typically modeled in REM/Rate when assessing compliance. Examples of other measures include lighting, appliances, and photovoltaics.

7.1.4 Overall Building UA Compliance Path (Trade-off)

The Overall Building UA trade-off path is an approach that compares the overall UA-value of the as built home to the overall UA-value of an identical home insulated to meet the 2006 IECC prescriptive requirements (reference home). The overall UA-value of a home is calculated by summing the UA-value for the primary shell measures of the home (e.g. ceiling, above grade walls, frame floors, etc.). This path allows for trade-offs in insulation values between the various shell measures. In other words, if code specifies R-19 in the walls and R-38 in the ceiling, a home may be able to comply with code by installing R-13 wall insulation and R-50 attic insulation. This analysis was conducted in REM/Rate, but the results should be the same as those produced in the REScheck software developed by BECP.[17]

7.2 Mandatory Duct Insulation Requirements

According to the 2006 IECC and the seventh edition of the Massachusetts building code, it is a mandatory requirement that supply ducts located in unconditioned space have a minimum of R-8 insulation. During the 50 site visits at non-ENERGY STAR homes, NMR and KEMA raters rarely identified R-8 insulation on supply ducts. The supply duct insulation requirement is a mandatory code requirement and therefore it cannot be ignored by using the Overall Building UA trade-off compliance approach or the Annual Energy Cost compliance approach.[18]

Both samples, the 50 non-ENERGY STAR homes and the 50 ENERGY STAR homes, included a number of homes that did not comply with the mandatory duct insulation requirement, suggesting this requirement was not enforced. If a home was modeled with less than R-8 insulation on supply ducts, REM/Rate considered it non-compliant when running the 2006 IECC Overall Building UA- and Annual Energy Cost compliance reports.

Many of these homes were otherwise compliant—the homes either had a lower overall UA-value or a lower annual energy cost than the reference home. In these cases, the percentage that the design home exceeded code was manually calculated; for the purposes of this study these homes were considered code compliant, though they were flagged as failing the mandatory duct insulation requirements.[19] This issue was more profound when assessing compliance via the

[17] http://www.energycodes.gov/rescheck/download.stm

[18] This requirement can be ignored using the Home Energy Rating compliance approach as REM/Rate is not a code compliance software, rather it is an energy modeling software. A home can still achieve a HERS index of 100 or less if it does not meet this requirement.

[19] REM/Rate also flags homes that fail to meet a maximum U-factor for windows. It is very rare that a new house would fail to meet this requirement, but there was one home that failed to meet the window requirements and

Annual Energy Cost compliance path than the Overall Building UA trade-off path. The number of homes passing under the Annual Energy Cost compliance path was far greater than the number of homes passing under the Overall Building UA path increased.

7.3 Compliance Data Using the Checklist

The checklist was developed by PNNL to assess code compliance under either the prescriptive path, the Overall Building UA trade-off path, or the performance path (Annual Energy Cost compliance). The checklist covers many items with the understanding that not all checklist items are applicable to every home.

The checklist works on a point system—the system is structured such that each checklist item is worth a given number of points. If an item is deemed to be compliant then the house receives the total possible points for that item, conversely if that item is deemed to be non-compliant then the house does not receive any points. The checklist accounts for the fact that not all items are applicable to all homes by allowing raters to specify an item as "N/A" or "Not Observable". When "N/A" or "Not Observable" is input, the possible points and the points received for that measure both default to zero, essentially removing that item from the compliance analysis.

The checklist was developed to assess 90% code compliance and therefore any home that has a compliance percentage equal to or greater than 90% is considered compliant under the inspector/rater selected compliance approach.[20] The equation used to calculate checklist compliance is listed below:

$$Compliance = \frac{Points\ Received}{Points\ Possible}$$

While this approach accounts for variance among homes by adjusting the total possible points, it also allows for a compliance assessment based on an extremely low number of total possible points. For example, during the NMR and KEMA site visits there were many checklist items that were listed as not observable due to the post occupancy nature of the study (See page 16). In one case a home was only eligible for 26 possible points (about nine checklist items). Given the point structure of the checklist this home could have been considered compliant based on eight or nine checklist items, regardless of the significance of those measures.

7.4 On-site Inspection Compliance Results

Table 7-1 displays the minimum, median, maximum, and average compliance results for the 50 homes that were visited by NMR and KEMA raters. The first half of the table displays the code

otherwise complied based on the Annual Energy Cost compliance analysis. This home was treated the same as homes with ducts that failed to meet the mandatory insulation requirement—it was considered compliant but flagged as failing the maximum U-factor mandatory requirement.

[20] The checklist has a section for inspectors/raters to identify which compliance path they are using to achieve compliance.

compliance results using the 2006 IECC checklist (prescriptive path). Using this approach, the average compliance was 45.2%; no homes were compliant (achieved 90% compliance) under this path. The Annual Energy Cost and the Overall Building UA trade-off compliance paths are presented as a percentage above or below code. A positive percentage represents homes meeting or exceeding code, while a negative percentage represents homes below code. On average, the sample of 50 non-ENERGY STAR homes was -0.3% below code using the Annual Energy Cost compliance path, and -31.2% below code using the Overall Building UA trade-off approach; 50% of homes were compliant under the Annual Energy Cost compliance path and no homes were compliant under the Overall Building UA trade-off path. Finally, 92% of the homes achieved a HERS index of 100 or lower and, thus, were compliant with the 2006 IECC under the Home Energy Rating compliance path.

Table 7-1: Compliance Results for On-site Visits

Statistic	Checklist			REM/Rate Compliance		
	Points Possible	Points Received	Compliance Percentage	HERS Index	Energy Cost Compliance % Pass/Fail	UA Compliance % Pass/Fail
Sample Size	*50*	*50*	*50*	*50*	*50*	*50*
Minimum	26	7	16.7%	64	-52.2%	-154.2%
Median	35.5	16	45.2%	81	0.1%	-26.7%
Maximum	54	28	66.7%	112	27.9%	-8.1%
Average	**36.6**	**16.6**	**45.2%**	**83.3**	**-0.3%**	**-31.2%**
Percent of compliant homes			**0%**	**92%**	**50%**	**0%**

7.4.1 Variability in Compliance Based on Approach

There are a number of reasons for the variability in compliance across the four compliance paths. For the non-ENERGY STAR homes, the checklist approach assessed compliance under the prescriptive path. These homes were assessed on an item by item basis, which typically leads to lower compliance rates as builders struggle to meet the requirements of specific items. For the 50 non-ENERGY STAR homes there were a number of assumptions that added to the low compliance rates. These assumptions and the associated checklist items are listed below:

- *Construction drawings and documentation available:* if plans were not available on site this item was marked as non-compliant.[21]
- *HVAC loads calculations:* this item was marked as non-compliant for all 50 non-ENERGY STAR homes as load calculations were never verifiable on site.
- *Air sealing checklist items:* these items were consistently marked as being unobservable given the post occupancy nature of the study. Most of the homes visited by NMR and

[21] If plans were available on site they had to sufficiently demonstrate energy code compliance; some did not.

KEMA would have been compliant with the air sealing measures had the 2006 IECC allowed compliance to be assessed via a blower door test and the ACH50 results.[22]

- *Ceiling insulation R-value:* if ceiling insulation had an R-value of less than R-38 it was considered non-compliant. The 2006 IECC allows for R-30 insulation in the ceiling if the insulation is not compressed at the eaves. To meet this requirement almost certainly requires a raised heel truss which was rarely seen, if at all, during the site visits.
- *Heating and cooling equipment type and capacity as per plans:* this item was marked as being non-compliant for all 50 non-ENERGY STAR homes as load calculations were never verifiable on site.

Similar to the checklist approach, the Overall Building UA trade-off approach performed poorly in terms of compliance. On average, the 50 non-ENERGY STAR homes were estimated to be 31.2% below code. None of the 50 non-ENERGY STAR homes were compliant with the 2006 IECC under either the checklist or Overall Building UA trade-off approach.

When assessed under the performance paths (i.e. the Home Energy Rating path and the energy cost compliance path), compliance rates increased significantly. Using the Annual Energy Cost compliance path, the 50 non-ENERGY STAR homes were found to be 0.3% below code on average, with 50% of them being compliant. The Home Energy Rating path was even more impressive with a 92% compliance rate.

There are a number of reasons for the jumps in compliance using the performance paths versus the prescriptive paths (i.e. the checklist and Overall Building UA trade-off paths). The performance paths allow homes to be assessed as a system. This allows for whole building tradeoffs with respect to efficiency and energy usage. Key inputs such as high efficient HVAC equipment, low air leakage, and low duct leakage are considered in a performance approach. These items are identified on the checklist, but they are given much more weight in the REM/Rate models.[23]

Within the performance paths, the Home Energy Rating path is a much easier route to compliance than the Annual Energy Cost compliance path. This is evident by the overall compliance percentages of the 50 non-ENERGY STAR homes inspected (92% compliant under the Home Energy Rating path and 50% compliant under the Annual Energy Cost path). The Annual Energy Cost compliance path only considers costs related to heating, cooling, and domestic hot water. The HERS index is based on those areas in addition to lights, appliances, on-site power generation, and other measures. In other words, the HERS index allows for more tradeoffs in achieving compliance than the Annual Energy Cost compliance path. Another builder benefit to achieving compliance through the Home Energy Rating path is that some mandatory requirements can be avoided. REM/Rate is not code compliance software, and does

[22] The 2009 IECC allows air sealing to be considered compliant if the ACH50 for the house is 7 or lower.
[23] The 2006 IECC gives credit to high efficiency HVAC systems complying under the performance path. It should be noted that this does not apply to the 2009 IECC—in the 2009 code, homes are given no additional credit for high efficiency HVAC equipment.

not concern itself with code when calculating a HERS index. On the other hand, the Annual Energy Cost compliance path will fail a home for not meeting mandatory code requirements such as duct insulation.

7.5 ENERGY STAR Home Compliance Results

Table 6-2 displays the minimum, median, maximum, and average compliance results for the 50 ENERGY STAR homes for which 2006 IECC checklists were completed. The first half of the table displays code compliance results using the 2006 IECC checklist to assess compliance for homes following a performance compliance approach. As shown, 88% or 44 of the 50 homes complied under this approach; individual home compliance rates ranged from 78% to 100%, the average was 96% and the median 100%. What these high compliance rates mean is that almost every checklist item that could be observed complied with code. Also, remember that since these homes all have HERS indices well below 100, complying with code following the Home Energy Rating compliance path, checklist items such as insulation R-values are considered compliant if they are below prescriptive code requirement levels.

Table 7-2: Compliance Results for ENERGY STAR Homes

Statistic	Checklist			REM/Rate Compliance		
	Points Possible	Points Received	Compliance Percentage	HERS Index	Energy Cost Compliance % Pass/Fail	UA Compliance % Pass/Fail
Sample Size	*50*	*50*	*50*	*50*	*50*	*50*
Minimum	29	26	78%	25	4.5%	-51.5%
Median	57	53	100%	64	24.1%	-1.3%
Maximum	85	85	100%	83	62.8%	34.0%
Average	**55**	**53**	**96%**	**63**	**26.8%**	**-4.2%**
Percent of compliant homes			**88%**	**100%**	**100%**	**46%**

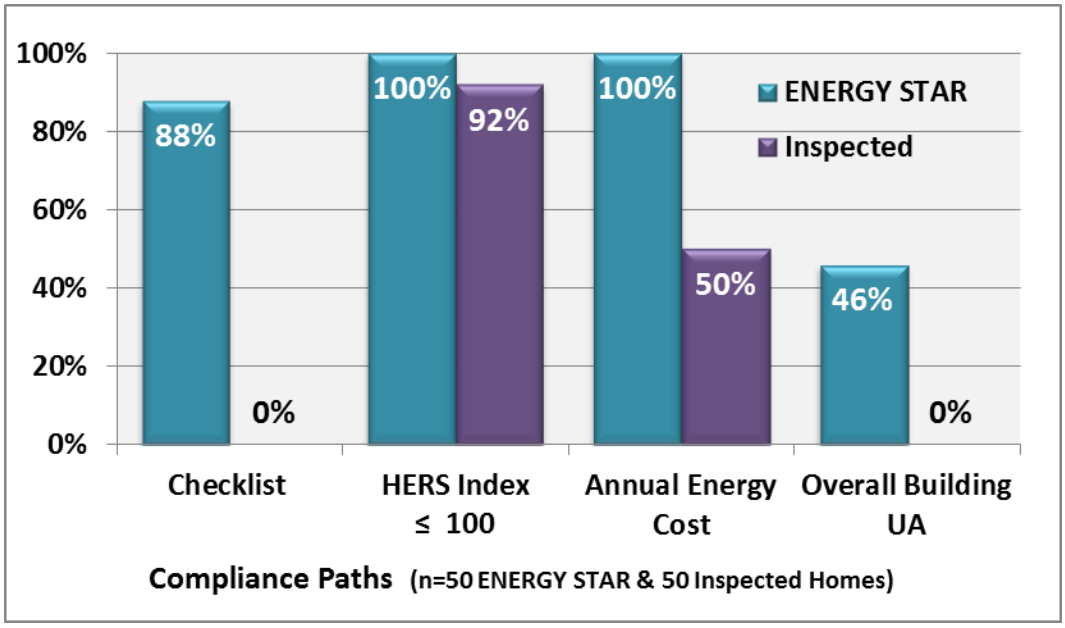
Compliance results under the Annual Energy Cost compliance and Overall Building UA trade-off compliance paths are presented as a percentage above or below code. A positive percentage represents homes meeting or exceeding code, while a negative percentage represents homes below code. All 50 ENERGY STAR homes comply under the Home Energy Rating and Annual Energy Cost compliance paths. Individual home HERS indices range from 25 (the best) to 83. Individual homes exceed compliance requirements under the Annual Energy Cost compliance approach by 4.5% to 62.8%. The poorest compliance rates, by far, are under the overall UA compliance path; only 46% of homes comply. The percentages by which homes failed to meet or exceeded UA compliance range from -51.5% to 34%; the average is -4.2% and the median -1.3%. As described earlier, the Home Energy Rating and Annual Energy Cost compliance paths allow more flexibility and trade-offs, which facilitate making construction decisions based on

looking at the whole house as a system rather than meeting individual measure prescriptive code requirements.

7.6 Comparing Non-ENERGY STAR and ENERGY STAR Results

Figure 7-1 shows a comparison of compliance results for the ENERGY STAR and non-ENERGY STAR (inspected) homes. This figure displays the percentage of homes that were in compliance using each of the four compliance paths. Across the board ENERGY STAR homes displayed a higher overall compliance than inspected homes. The two samples were most similar, in terms of compliance, when assessed using the Home Energy Rating compliance path; under this path 100% of the ENERGY STAR homes and 92% of the non-ENERGY STAR homes were compliant.

Figure 7-1: Percentage of Homes in Compliance—All Paths[24]



7.6.1 Comparing the Checklist Results

In order to compare the non-ENERGY STAR and ENERGY STAR checklist results it is important to understand that the checklists were completed assuming two different compliant paths. NMR and KEMA raters completed the checklist using a prescriptive approach, while ENERGY STAR raters used the performance approach.

Using the prescriptive approach NMR and KEMA raters found, on average, only 45.2% of the observable items on the checklist were in compliance. HERS raters, assessing the checklist from a performance approach, found that 96% of the observable checklist items were in compliance. The key difference here is that raters for the non-ENERGY STAR homes were looking at each

[24] The checklist results are not a direct comparison as the ENERGY STAR homes were assessed using the performance compliance path and the inspected homes were assessed using the prescriptive path.

item individually to see if it complied, whereas raters assessing ENERGY STAR homes were accounting for trade-offs, given the nature of the performance approach. On the whole, 88% of the ENERGY STAR homes passed using the 2006 IECC checklist, compared to none of the non-ENERGY STAR homes (Table 7-3).

Table 7-3: Comparison of Checklist Compliance

	Non-ENERGY STAR	ENERGY STAR
Sample Size	*50*	*50*
Compliance path	Prescriptive Path	Performance Path
Minimum compliance percentage	16.7%	78%
Median compliance percentage	45.2%	100%
Maximum compliance percentage	66.7%	100%
Average compliance percentage	**45.2%**	**96%**

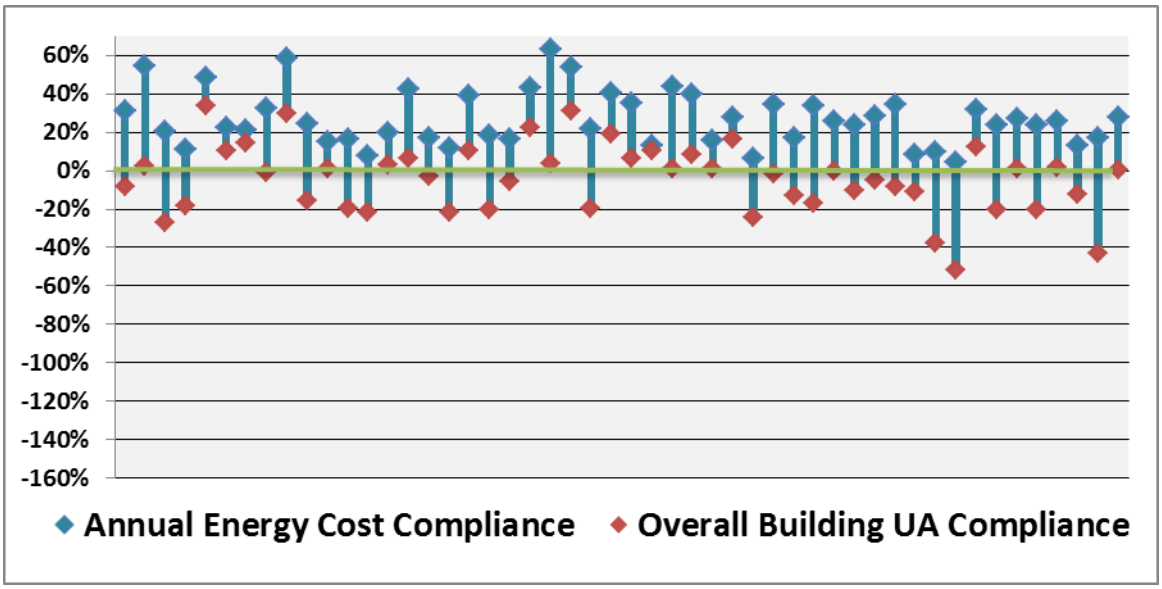
While the compliance paths assessed were different between the two samples the core calculations of the checklist function in the same way. If a checklist item is determined to be applicable (and observable) then that item is provided with a number of possible points. Before this study started it was assumed that ENERGY STAR raters would be able to observe more checklist items than raters using the checklist in a completed home. This assumption was based on the fact that HERS raters must visit a building multiple times during the construction process in order to certify a home for the Massachusetts New Homes with ENERGY STAR Program. Ultimately, this assumption was realized; the checklists for ENERGY STAR homes averaged 55 possible points compared to 36.6 possible points for the non-ENERGY STAR homes (Table 7-1 & Table 7-2). This equates to the ENERGY STAR checklists having somewhere between six and seven checklist items more than the non-ENERGY STAR checklists, assuming three points per item, which is common in the checklist.

HERS raters assessing ENERGY STAR homes and the NMR and KEMA raters populated the checklist slightly differently given the different approaches used. One interesting difference was the use of the "Not Observable" selection on the checklist. NMR and KEMA raters knew exactly what data needed to be collected when they visited the 50 non-ENERGY STAR homes. For this reason, these raters were able to determine exactly which items were "Not Observable" and which items were "Not Applicable (N/A)". On the other hand, the ENERGY STAR raters were asked to assess the checklist after they had collected all of the necessary data to certify a home through the Massachusetts New Homes with ENERGY STAR Program. This led the raters to identify some items as "Not Observable" when in fact they just were not observed. That is to say, these items were on site and were visible at the time of inspection, but the raters did not need to collect data on said items and consequently did not observe them.

7.6.2 Comparing Annual Energy Cost and Overall Building UA Compliance

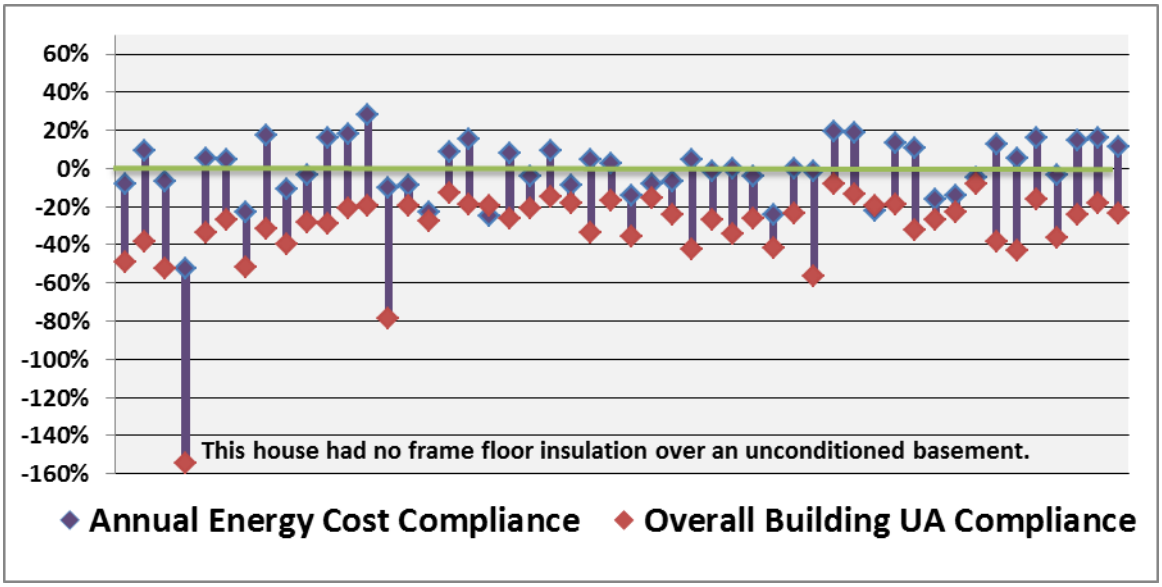
Figure 7-2 shows a comparison of the Annual Energy Cost and Overall Building UA trade-off compliance results for the 50 ENERGY STAR homes. This figure presents the percent above or below code each of these homes was under each compliance path. For all 50 homes, the Annual Energy Cost compliance path produced a greater level of compliance than the Overall Building UA approach. This speaks volumes to the energy saving advantages of the Annual Energy Cost compliance path. Under this path the reference home is modeled based on the 2006 IECC prescriptive requirements. These are the same prescriptive requirements used to determine compliance with the Overall Building UA trade-off approach. The major difference is that the Annual Energy Cost compliance path takes into account important energy-related characteristics from areas other than the building shell. The most important of these areas are more often than not air leakage, duct leakage, and equipment efficiency. When these factors are taken into account the individual homes are significantly more compliant relative to the Overall Building UA trade-off approach. Figure 7-2 shows the individual home variability between the two paths, which is also expressed in the overall compliance numbers—100% of ENERGY STAR homes were compliant under the Annual Energy Cost compliance path compared to 42% under the Overall Building UA trade-off approach.

Figure 7-2: Comparison of Annual Energy Cost and Overall Building UA Compliance—ENERGY STAR Homes



Similar to what was shown in Figure 7-2, Figure 7-3 shows a comparison of compliance rates under the Annual Energy Cost and Overall Building UA trade-off approaches for the 50 inspected homes. The same trends hold true for the inspected homes; there is a wide variation in individual home compliance when comparing the two compliance paths. As was true for the ENERGY STAR homes, the Annual Energy Cost compliance path showed greater compliance than the Overall Building UA trade-off approach for all 50 inspected homes.

Figure 7-3: Comparison of Annual Energy Cost and Overall Building UA Compliance—Inspected Homes

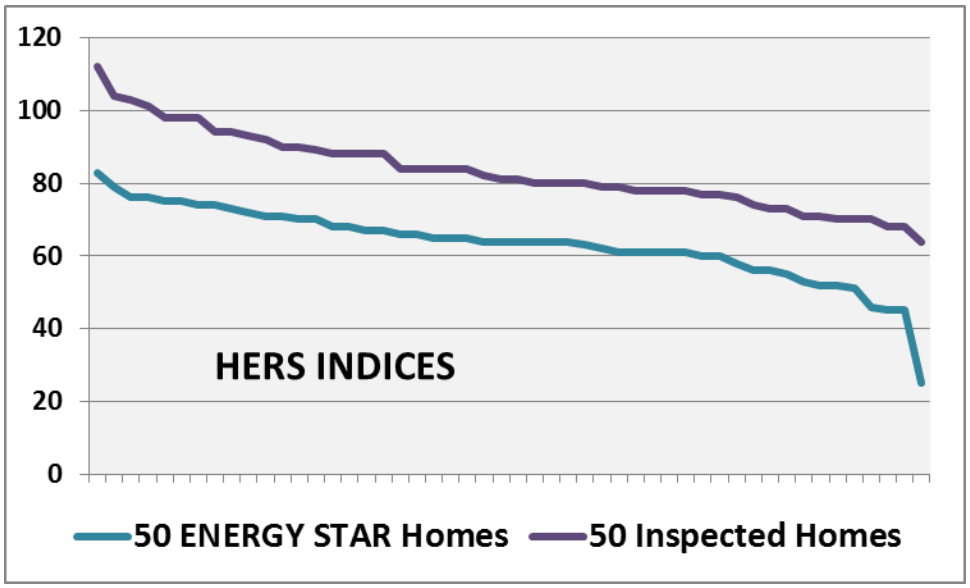


For both samples, the 50 ENERGY STAR homes and the 50 non-ENERGY STAR homes, the trends between the Annual Energy Cost and the Overall Building UA trade-off compliance paths hold true. In short, there is considerable variability between individual Annual Energy Cost compliance and Overall Building UA trade-off compliance paths. Both samples also show a fair amount of variability across all 50 homes, with some homes being significantly above or below code and others just meeting code.

7.6.3 Comparing the HERS Indices

Just as the ENERGY STAR and inspected homes show similar trends with regards to the compliance paths discussed above, they also show a similar trend with respect to the HERS indices across the respective samples of 50 homes. Both samples show a few high and low HERS indices, but have a steady curve from one end to the other. One thing is clear from all of these figures, particularly Figure 7-4, the ENERGY STAR homes are a tier above the inspected non-ENERGY STAR homes. The trends between the samples are similar, but the ENERGY STAR homes have proven themselves to be substantially more energy efficient.

Figure 7-4: ENERGY STAR and Inspected Home HERS Indices



Appendix A Individual Home Compliance Rates

This appendix presents the compliance results for all of the sites evaluated for this report: 50 ENERGY STAR-qualified homes and 50 non-ENERGY STAR-qualified homes built at the end of the 2006 IECC cycle.

Table A-1: Individual Compliance Results for On-Site Inspections

Site ID	Checklist				REM/Rate Code Compliance Reports		
	Points Possible	Points Received	Compliance Percentage	Pass/ Fail	HERS Index	2006 IECC Annual Energy Cost Compliance % Pass or Fail	2006 IECC Overall Building UA Compliance % Pass or Fail
BARN-004	54	22	40.7%	Fail	84	-7.8%	-49.2%
BARN-031*	36	19	52.8%	Fail	76	9.2%	-38.2%
BARN-032	48	8	16.7%	Fail	84	-7.0%	-52.1%
BERK-006	35	12	34.3%	Fail	112	-52.2%	-154.2%
BERK-011*	39	13	33.3%	Fail	80	5.5%	-33.7%
BRIS-013*	33	11	33.3%	Fail	82	4.7%	-27.2%
BRIS-051	33	7	21.2%	Fail	92	-23.2%	-51.5%
BRIS-052*	48	25	52.1%	Fail	68	17.7%	-31.4%
BRIS-062	36	16	44.4%	Fail	84	-11.0%	-40.0%
BRIS-079	38	16	42.1%	Fail	80	-3.6%	-28.1%
ESS-004*	39	22	56.4%	Fail	71	16.0%	-28.8%
ESS-015*	42	19	45.2%	Fail	70	18.2%	-20.8%
ESS-032	39	9	23.1%	Fail	64	27.9%	-19.7%
FRAN-006	29	12	41.4%	Fail	104	-10.0%	-78.6%
FRAN-009	33	14	42.4%	Fail	98	-9.0%	-19.6%
HAMP-003	33	13	39.4%	Fail	93	-23.2%	-27.6%
HAMP-003-2*	42	28	66.7%	Fail	78	8.9%	-12.8%
HAMP-009	41	24	58.5%	Fail	70	15.1%	-19.1%
HAMP-009-2	34	15	44.1%	Fail	98	-24.9%	-19.8%
HAMP-016	33	13	39.4%	Fail	77	8.3%	-26.5%
MID-008	36	23	63.9%	Fail	88	-4.0%	-20.9%
MID-024*	42	22	52.4%	Fail	73	9.1%	-14.6%
MID-041	38	10	26.3%	Fail	90	-8.5%	-18.2%
MID-046*	45	23	51.1%	Fail	78	4.4%	-33.7%
MID-083*	37	17	45.9%	Fail	81	2.4%	-16.7%
MID-094	33	10	30.3%	Fail	98	-14.0%	-35.6%

Site ID	Checklist				REM/Rate Code Compliance Reports		
	Points Possible	Points Received	Compliance Percentage	Pass/ Fail	HERS Index	2006 IECC Annual Energy Cost Compliance % Pass or Fail	2006 IECC Overall Building UA Compliance % Pass or Fail
MID-107	41	24	58.5%	Fail	79	-7.8%	-15.3%
MID-136	33	16	48.5%	Fail	89	-6.5%	-24.1%
MID-155*	42	22	52.4%	Fail	84	4.4%	-42.1%
NORF-003	36	19	52.8%	Fail	90	-1.6%	-26.9%
NORF-032*	33	13	39.4%	Fail	73	0.2%	-34.6%
NORF-042	33	13	39.4%	Fail	88	-4.4%	-26.0%
NORF-051	33	10	30.3%	Fail	101	-24.0%	-42.0%
PLY-003	35	21	60.0%	Fail	81	-0.1%	-23.4%
PLY-008	33	13	39.4%	Fail	84	-1.3%	-56.3%
PLY-010*	42	22	52.4%	Fail	70	19.3%	-8.3%
PLY-013	31	14	45.2%	Fail	74	19.0%	-13.7%
PLY-029	35	18	51.4%	Fail	103	-22.1%	-19.5%
PLY-061	33	11	33.3%	Fail	78	13.1%	-19.0%
SUF-001	26	13	50.0%	Fail	71	11.0%	-32.3%
WORC-002	35	15	42.9%	Fail	94	-16.1%	-26.8%
WORC-003	33	13	39.4%	Fail	94	-14.2%	-22.8%
WORC-005	31	17	54.8%	Fail	88	-4.9%	-8.1%
WORC-013	31	14	45.2%	Fail	80	12.8%	-38.1%
WORC-025*	39	22	56.4%	Fail	79	5.2%	-42.9%
WORC-036[25]	30	20	66.7%	Fail	68	15.8%	-16.1%
WORC-060	36	19	52.8%	Fail	88	-3.4%	-36.1%
WORC-065**	39	20	51.3%	Fail	77	14.5%	-23.9%
WORC-038*	41	24	58.5%	Fail	78	16.0%	-18.1%
WORC-045*	35	15	42.9%	Fail	80	11.3%	-23.8%

* Homes that are compliant with either the Annual Energy Cost or UA approach, but fail the duct insulation requirements.

** Homes that are compliant with either the Annual Energy Cost or UA approach, but fail the maximum U-factor glazing requirements.

[25] For this home the basement walls were assumed to be the same as the reference home for the UA-tradeoff compliance assessment.

Table A-2: Individual Compliance Results for ENERGY STAR Homes

Site ID	Checklist				REM/Rate Code Compliance Reports		
	Points Possible	Points Received	Compliance Percentage	Pass/ Fail	HERS Index	2006 IECC Annual Energy Cost Compliance % Pass or Fail	2006 IECC Overall Building UA Compliance % Pass or Fail
ABA-1*	48	47	98%	Pass	61	31.1%	-8.2%
ABA-2	36	35	97%	Pass	25	54.6%	2.2%
ABA-3*	59	46	78%	Fail	65	20.1%	-27.3%
ABA-4	35	29	83%	Fail	76	10.8%	-18.1%
BD-01	50	45	90%	Pass	45	48.4%	34.0%
BD-02	45	43	96%	Pass	71	22.2%	10.2%
BD-03*	64	59	92%	Pass	68	21.3%	14.3%
BD-04	76	76	100%	Pass	64	32.2%	-1.0%
BD-05	71	69	97%	Pass	52	58.6%	29.9%
BD-06*	58	56	97%	Pass	67	24.1%	-15.6%
BD-07*	58	53	91%	Pass	61	15.1%	1.3%
BD-08*	58	53	91%	Pass	75	16.4%	-19.7%
BD-09*	58	56	97%	Pass	83	7.9%	-21.9%
BD-10*	64	61	95%	Pass	66	20.0%	2.8%
CER-01	80	80	100%	Pass	56	42.7%	6.3%
CER-02	74	74	100%	Pass	64	16.9%	-3.3%
CER-03*	59	56	95%	Pass	76	11.6%	-21.6%
CER-04	68	65	96%	Pass	53	39.0%	10.3%
CET-01*	42	42	100%	Pass	67	18.3%	-20.1%
CET-02*	50	50	100%	Pass	73	16.2%	-5.7%
CET-03	42	42	100%	Pass	55	43.0%	22.5%
CET-04	85	85	100%	Pass	46	62.8%	3.5%
CET-05	47	47	100%	Pass	45	53.9%	31.0%
CET-06	47	47	100%	Pass	63	21.5%	-19.4%
CET-07	54	46	85%	Fail	58	40.7%	18.9%
CSG-01	68	68	100%	Pass	62	35.2%	6.3%
CSG-02	42	42	100%	Pass	74	12.9%	10.7%
CSG-03	56	55	98%	Pass	52	43.6%	0.7%
CSG-04*	62	62	100%	Pass	56	39.8%	8.3%
CSG-05*	47	47	100%	Pass	70	15.8%	1.2%
CSG-06	61	61	100%	Pass	60	27.9%	16.6%

Site ID	Checklist				REM/Rate Code Compliance Reports		
	Points Possible	Points Received	Compliance Percentage	Pass/ Fail	HERS Index	2006 IECC Annual Energy Cost Compliance % Pass or Fail	2006 IECC Overall Building UA Compliance % Pass or Fail
CSG-07	54	49	91%	Pass	71	6.5%	-24.6%
CSG-08	71	71	100%	Pass	61	34.1%	-1.6%
CSG-09	53	53	100%	Pass	68	16.8%	-13.3%
CSG-10*	58	56	97%	Pass	51	33.4%	-16.8%
CSG-11*	60	56	93%	Pass	64	25.9%	-0.1%
CSG-12	53	43	81%	Fail	70	24.0%	-10.1%
CSG-13*	55	53	96%	Pass	64	28.2%	-4.9%
EEA-01	30	26	87%	Fail	61	34.4%	-8.1%
GDS1*	38	38	100%	Pass	74	8.4%	-11.2%
GDS2*	38	38	100%	Pass	75	9.9%	-38.0%
GDS3*	44	44	100%	Pass	79	4.5%	-51.5%
GDS4*	44	44	100%	Pass	61	32.0%	12.6%
GDS5	59	59	100%	Pass	64	23.9%	-20.0%
GDS6*	59	59	100%	Pass	65	27.1%	0.7%
GDS7	29	29	100%	Pass	60	23.9%	-20.0%
GDS8*	57	57	100%	Pass	64	25.5%	1.9%
GDS9	57	57	100%	Pass	72	12.8%	-12.0%
SEA1	57	48	84%	Fail	65	17.3%	-43.2%
SEA2	57	57	100%	Pass	66	27.5%	0.4%

* Homes that are compliant with either the Annual Energy Cost or UA approach, but fail the duct insulation requirements.