



To: Kim Oswald

From: NMR Group, Inc., Cadmus, and Dorothy Conant

Date: October 10, 2012

Re: 2011 Baseline Study Homes: Analysis of Potential Code Compliance under Four Compliance Paths

This memo addresses potential code compliance of 2011 Baseline Study homes under four compliance paths. Compliance under the prescriptive path is assessed by looking at the percent of homes that meet each prescriptive requirement and the percent of prescriptive requirements met in each home. In addition to producing HERS (Home Energy Rating System) indices, the basis of a Home Energy Rating compliance path, the REM/Rate™ software provides the following two compliance reports:

- UA: 2006 IECC Overall Building UA Compliance
- Energy Cost: 2006 IECC Annual Energy Cost Compliance

An analysis of compliance under the four paths was conducted to assess the likelihood of homes meeting requirements under different types of compliance paths. The purpose of this effort was not to assess code compliance for each inspected home, or to evaluate code enforcement. The REM/Rate compliance path calculations are similar to, but not identical to, how code officials assess compliance. Therefore, the results presented here are not indicative of actual code compliance but serve as a tool for assessing how differently the baseline homes would likely perform under different compliance paths.

Summary

Compliance of the inspected homes was lowest when determined using the Overall Building UA trade-off approach. On average, the inspected homes are estimated to be 27% below code using this approach and none of the homes are compliant with IECC 2006. When assessed using the performance compliance paths (i.e., the Home Energy Rating path and the Annual Energy Cost compliance path), compliance rates were determined to be much better. Using the Annual Energy Cost compliance path, 56% of the homes were determined to comply with the code and the average compliance was found to be 3% above code on average. The Home Energy Rating path gave even higher compliance rates—96% of the homes comply using this method and the average compliance is 18% better than code. These results suggest most homes would find it easier to comply using the Home Energy Rating path than the Annual Energy Cost compliance path.

Compliance Paths

In Connecticut, as in many other places, performance methods are usually used to determine code compliance, rather than relying on the prescriptive standards provided in 2006 and 2009 International Energy Conservation Code (IECC) prescriptive path code requirements. Homes that fail to meet one or more of the 2006 IECC prescriptive requirements may very well meet the requirements of other code compliance paths or tools, such as REScheck. REScheck, a primary code compliance tool used by Connecticut builders, allows trade-offs between R-values and U-values to show code compliance by trading off higher R-values in one component for lower R-values in another. The authors of this study do not and could not replicate what code officials would assess.

Prescriptive Compliance Path

Prescriptive path refers to a compliance path under which various aspects of a home are inspected individually to determine compliance with prescriptive requirements. 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., floor insulation installation quality)

In this report, compliance under the prescriptive path is assessed by looking at the percent of homes that meet each prescriptive requirement and the percent of prescriptive requirements met in each home.

Home Energy Rating Compliance Path (Performance)

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 2004 IECC.¹ To calculate a HERS index, REM/Rate models the reference home to be configured similar to the as-built home (e.g., size, shape, orientation), but with the reference home efficiency measures based on the 2006 IECC prescriptive requirements. A home built precisely to 2004 IECC prescriptive code requirements should score a HERS index of 100. A home that is more energy efficient will have a HERS index less than 100. Several states allow for compliance under the Home Energy Rating Path, with varying HERS scores being considered compliant. For example, in Massachusetts, homes were considered compliant with the 2006 IECC if they achieved a HERS rating of 100 or less.² Connecticut does not currently offer this type of compliance path.

¹ This was verified by Brian Christensen (Architectural Energy Corporation) in an email message sent on May 15, 2012.

² Massachusetts has since adopted the 2009 IECC and a HERS rating of 75 or less is now required to be considered compliant.

Annual Energy Cost Compliance Path (Performance)

The Annual Energy Cost compliance path is a performance path very similar to the Home Energy Rating path for compliance, though there are some important differences. The Home Energy Rating path uses the 2004 IECC reference home and individual states offering this compliance path choose the HERS index (something less than or equal to 100) required to comply under this path. Similar to the Home Energy Rating path, the Annual Energy Cost compliance path is based on REM/Rate models, but this path compares the as-built home to the 2006 IECC reference home, not the 2004 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 water heating costs. This compliance path does not consider other factors that are typically modeled in REM/Rate when assessing compliance. Examples of other measures not addressed are lighting, appliances, and photovoltaics.

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 built to meet the 2006 IECC prescriptive requirements (reference home). The overall UA-value of a home is calculated by summing the UA-values for the primary shell measures of the home (e.g., ceilings, above-grade walls, frame floors, etc.). This analysis was conducted using REM/Rate. Although similar to the REScheck software developed by the Department of Energy and the Building Energy Codes Program (BECP)³ there are several key differences between the REM/Rate Overall Building UA approach and REScheck, particularly when assessing compliance under 2006 IECC. Differences include no mechanical tradeoffs, varying UA calculations for insulation installation, and more detailed framing inputs in REM/Rate. These differences typically result in REM/Rate producing much more conservative UA calculations than REScheck. In other words, it is much easier to comply with code under the UA trade-off approach using REScheck than it is using REM/Rate.

Comparative Results

Table 1 displays the minimum, maximum, average, and median results for the prescriptive and REM/Rate compliance paths for the 69 inspected homes. The first half of the table compares efficiency results from checks of ten prescriptive requirements. On average, homes meet or exceed 50% of the 2006 IECC prescriptive requirements applicable to the home. The Annual Energy Cost and the Overall Building UA trade-off 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 sampled homes are 3.2% above code using the Annual Energy Cost compliance path, and 27.2% below code using the Overall Building UA trade-off approach. In other words, on average, the sampled homes have annual energy costs that are 3.2% less than the 2006 IECC reference home and overall UA

³ <http://www.energycodes.gov/rescheck/download.stm>

values are 27.2% higher than the 2006 IECC reference home (lower UA values result in compliance). More than one-half (56%) of homes are compliant under the Annual Energy Cost compliance path and no homes are compliant under the Overall Building UA trade-off path. Finally, 96% of the homes comply with 2006 IECC assuming a HERS rating of 100 or less is satisfactory for compliance.

Table 1: Prescriptive and REM/Rate Results Comparisons

Statistic	Prescriptive			REM/Rate Compliance		
	Eligible Criteria	Criteria Met/Exceeded	Percent of Criteria Met	HERS Index*	Energy Cost Compliance % Pass/Fail	UA Compliance % Pass/Fail
Minimum	2.0	0.0	0%	62	-20%	-165%
Maximum	8.0	6.0	100%	102	30%	-1%
Average	4.9	2.5	50%	82	3%	-27%
Median	6.0	3.0	46%	82	2%	-19%
Percent of Homes Compliant				96%	56%	0%

*The lower the HERS index the more energy efficient.

Prescriptive Comparisons Detailed Results

Ten insulation characteristics were considered for comparison with the prescriptive standards. Table 2 on the next page shows the percentage of inspected homes that met or exceeded applicable 2006 IECC prescriptive insulation standards. The insulation requirements only changed for two measures from the 2006 IECC to the 2009 IECC. These measures are wood framed walls and ducts; compliance with the 2009 IECC prescriptive requirements for these measures is discussed below for informational purposes.⁴ As shown, 93% of homes that might have been subject to wood frame wall R-value requirements had insulation that comport with 2006 IECC requirements, but only 4% would meet with 2009 IECC requirements if they had been so required. Although only 23% of homes would meet the 2006 IECC duct insulation requirement of R-8 for all ducts, 52% of homes would have met with the 2009 IECC requirement of R-8 for attic supply ducts only, and R-6 for all other ducts. Forty-one percent of those homes that could have been subject to floor R-value requirements would have met the 2006 IECC requirements. While the percent of homes meeting an individual standard ranges from 23% to 93%, only 4% of homes might have met all applicable prescriptive standards.

⁴ All 69 inspected homes were built during years covered by 2006 IECC.

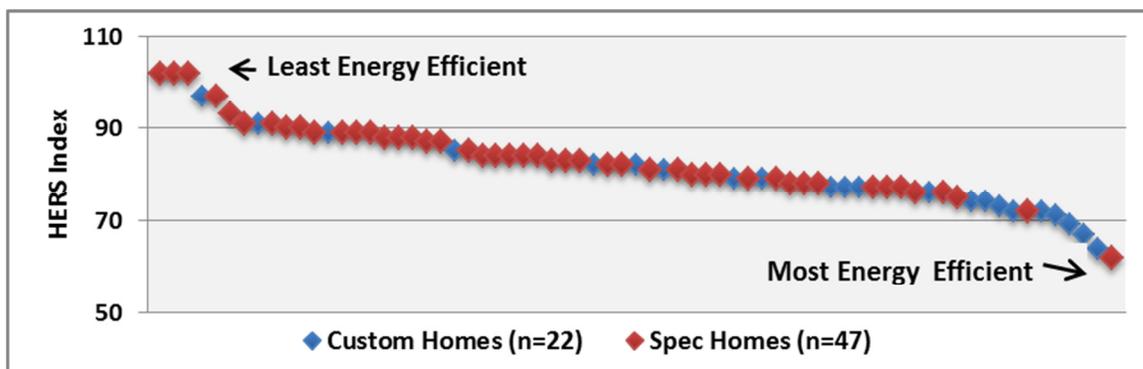
Table 2: Comparison with IECC Prescriptive Insulation Standards

Requirement	2006 IECC Prescriptive Requirement	Number of Inspected Homes Subject to Requirement	Percent of Homes Meeting 2006 IECC Requirement
Wood Framed Wall Insulation	R-19	69	93%
Foundation Wall	R-10/R-13 (cont./cavity)	18	83%
Duct Insulation	R-8 (all ducts)	62	23%
Flat Ceiling Insulation	R-38	68	29%
Cathedral Ceiling Insulation	R-38 (R-30 for ceilings up to 500 sq ft)	19	74%
Floors Over Unconditioned basement R-Value	R-30 or cavity filled	57	40%
Floors Over Unconditioned Garage R-Value	R-30 or cavity filled	30	60%
Floors over ambient (outside)	R-30 or cavity filled	11	55%
Floors over unconditioned (crawlspace)	R-30 or cavity filled	5	0%
All Floors Over Unconditioned Space	R-30 or cavity filled	63	41%
All Applicable IECC 2006 Requirements	-	69	4%

HERS Detailed Results

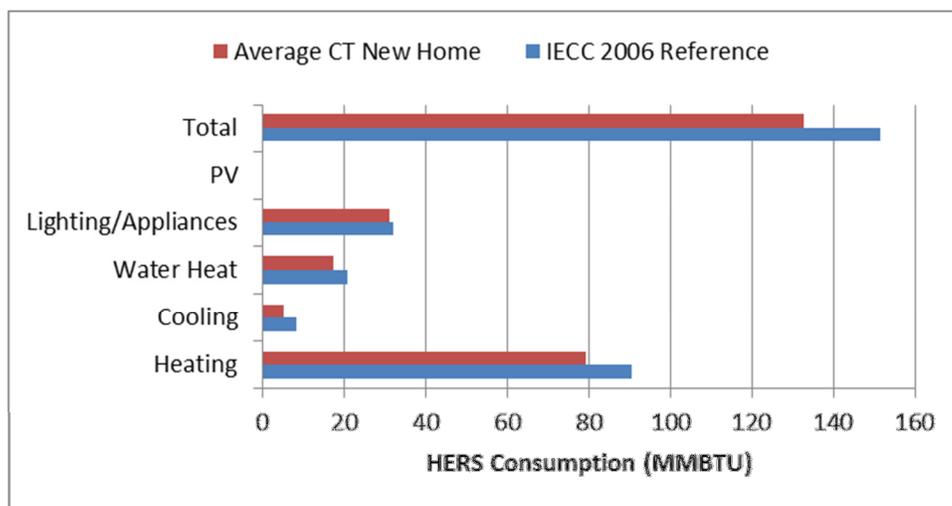
Ninety-six percent of homes achieved a HERS rating of 100 or lower indicating nearly all homes surpass 2006 IECC standards, assuming a HERS rating of 100 or less meets the standard of the HERS compliance path. In fact, 69 percent of homes had HERS ratings of 85 or less, meaning the majority of homes are 15% more efficient than the 2006 IECC reference home. Figure 1 shows the distribution of HERS ratings across the sample.

Figure 1: Distribution of HERS Scores



Across all end uses, the average home from the sample outperforms the 2006 IECC reference home. Figure 2 shows end use consumption for the average reference and design home.

Figure 2: HERS Consumption by End Use



On average, total HERS consumption is 13% lower for the inspected homes, compared to the 2006 IECC reference home. At an end use level, heating, cooling, and water heating are 13%, 38%, and 16%, respectively, more efficient in the average Connecticut new home studied, compared to the 2006 IECC reference home.

Annual Energy Cost Path (Performance) Detailed Results

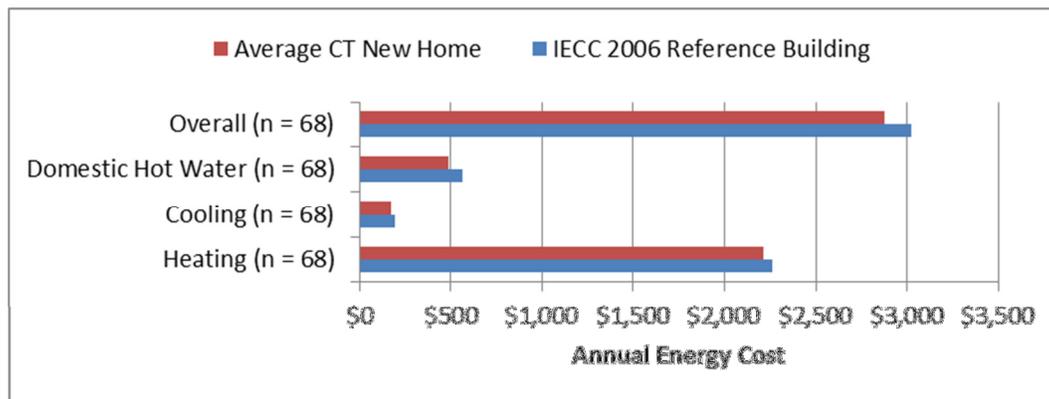
As shown in Table 3, 56% of the inspected homes were compliant under the Annual Energy Cost Compliance approach with overall annual energy costs lower than the 2006 IECC reference home.

Table 3: Energy Cost Path Results

End Use	n	Percent Compliant
Heating	68	54%
Cooling	68	82%
Domestic Hot Water	68	87%
Overall	68	56%

Overall performance is driven down by the heating end use. For the cooling and water heating end uses, 82% and 87% of homes have annual energy costs lower than the 2006 IECC reference home, respectively. On average, these two end uses combine to account for only 24% of the total annual energy costs considered for energy cost compliance. Heating accounts for the remaining 76% of total annual energy costs considered, and a little over one half (54%) of homes have annual heating costs lower than the 2006 IECC reference home. Still, across all end uses, the average Connecticut new home outperforms the reference home from an energy cost perspective. Figure 3 shows average annual energy costs by end use for the 2006 IECC reference home and Connecticut new homes.

Figure 3: End Use Energy Cost Comparison



Overall Building UA Compliance Path (Trade-Off) Detailed Comparisons

None of the homes satisfy the UA compliance path requirements. Areas over unconditioned spaces (such as basement and crawlspaces) rarely meet the standard. This is not to say that these components never meet prescriptive requirements, they do. UA compliance, when calculated in REM/Rate, accounts for compression and gaps in insulation, effectively lowering any given assembly R-value (or raising the U-value). These adjustments lead to component specific non-

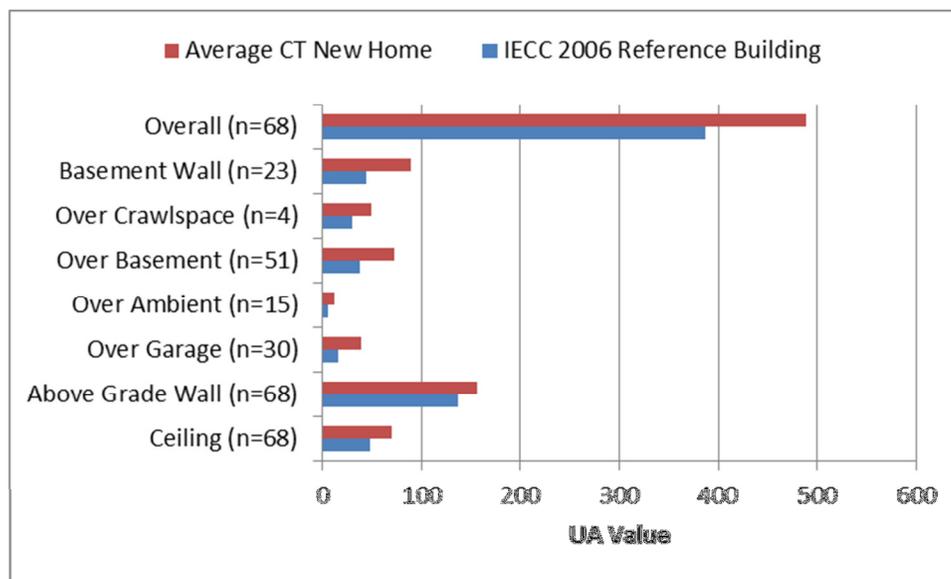
compliance under the UA trade-off path. Basement walls (26%) have the highest compliance percentage of any component with reliable data. Table 4 shows the percent of homes where the calculated UA value complies with the IECC 2006 requirement by component.

Table 4: UA Compliance by Surface

Component	n	Percent Compliant
Ceiling	68	19%
Above Grade Wall	68	1%
Over Garage	30	0%
Over Ambient	15	7%
Over Unconditioned Basement	51	0%
Over Unconditioned Crawlspace	4	0%
Basement Wall	23	26%
Overall	68	0%

Figure 4 compares average UA values from the sample to the 2006 IECC reference home's UAs by component and overall. It should be noted that under the UA compliance path, and in Figure 4, a home is considered to be in compliance if its UA value is less than that of the reference home.

Figure 4: UA Comparison



On average, observed overall UA values exceed reference UA values by 26%. The large difference in overall UA is driven by basement walls, ceilings, and floors over unconditioned basements. For these components, average “as designed” UA values exceed the average 2006 IECC reference UA value by 104%, 48%, and 89%, respectively.

Variability Based on Approach

Compliance of the inspected homes was lowest when determined using the Overall Building UA trade-off approach. On average, the inspected homes are estimated to be 27% below code using this approach and none of the homes are compliant with IECC 2006. Keep in mind, the Overall Building UA trade-off results are based on REM/Rate software and not the more commonly used REScheck software. While the REM/Rate Overall Building UA and REScheck approaches are similar, the following differences lead to more conservative UA calculations (higher UA values) in REM/Rate as opposed to REScheck.

- When assessing compliance with 2006 IECC, REScheck allows trade-offs with high efficiency mechanical equipment, REM/Rate does not.
- REScheck assumes a Grade I insulation installation for all shell measures while REM/Rate relies on the insulation installation grades input by raters.

When assessed using the performance compliance paths (i.e., the Home Energy Rating path and the Annual Energy Cost compliance path), compliance rates were determined to be much better. Using the Annual Energy Cost compliance path, 56% of the homes were determined to comply with the code and the average compliance was found to be 3% above code on average. The Home Energy Rating path gave even higher compliance rates—96% of the homes comply using this method and the average compliance is 18% better than code. These results suggest most homes would find it easier to comply using the Home Energy Rating path than the Annual Energy Cost compliance path.