MEEA REPORT ON MISSOURI RESIDENTIAL BUILDING ENERGY CODE PRACTICES STUDY

FINAL REPORT

July 29, 2016

Introduction

In March 2016, the Midwest Energy Efficiency Alliance (MEEA) was contracted by the Missouri Department of Economic Development Division of Energy (DED/DE) to collect data about current Missouri residential construction practices as they relate to the 2009 International Energy Conservation Code (IECC). This data collection effort was funded by DED/DE through a State Energy Program (SEP) grant received from the US Department of Energy (DOE). The Project Team consisted of MEEA who provided overall project management and data coordination services; the Cadmus Group (Cadmus) who provided on-site data collection services; and Verdatek Solutions, LLC (Verdatek) who provided builder recruitment services. Data analysis and estimates of potential savings through improved compliance will be provided by the Pacific Northwest National Laboratory (PNNL).

It is important to note that Missouri does not have a mandatory statewide code, although local jurisdictions can choose to adopt energy codes. The intent of this study was not to determine the compliance of individual homes with their respective local code requirements. The goal of this study is to examine a statistically-significant sample of new single-family homes being built in Missouri to determine current construction practices with respect to the 2009 International Energy Conservation Code.

Using a DOE prescribed data collection protocol[1], data was collected for a minimum of 63 observations (the minimum number required for statistical significance as determined by PNNL) for each of eight key energy code compliance categories:

Envelope Tightness (ACH50)	Window Solar Heat Gain Coefficient (SHGC)
Window U-Factor	Exterior Wall Insulation
Ceiling Insulation	High Efficacy Lighting
Foundation Insulation	Duct Leakage

In addition to these eight key items, sufficient data was collected to perform HVAC load calculations according to the Air Conditioning Contractors of America (ACCA) Manual J protocol. Under the DOE protocol, each home could be visited only once. This means that no one house ever provided data for all of the key items shown above. Ultimately, Cadmus visited 127 homes to collect the minimum of 63 observations for each of the key items. While on site the data collectors recorded their observations on other energy code compliance items "as available" for visual or physical inspection, there were no minimum number of observations required for these additional observations.

The report that follows highlights the process that was used to collect the data, issues encountered in the field, patterns of compliance and non-compliance, and lessons learned.

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1 https://www.energycodes.gov/sites/default/files/documents/drafts/042115_Residential_FOA_Guidance_Document_DRAFT.pdf

Overview of Project

Following is a brief overview of the work done for the project.

1. Hire field inspectors and outreach coordinator.
2. Develop statewide sampling plan.
3. Builder Recruitment by outreach coordinator.
4. Site Visits
5. Data Review and Inputting

Methodology

Sampling Plan

To obatain a statistically valid sample of observations; a statewide sampling plan was constructed in the following way. MEEA developed a county level Sampling Plan based on permit activity for the Combined Statistical Areas (CSA) and Metropolitan Statistical Areas (MSA) and of the state, and the plan was approved by PNNL. On average, these areas accounted for approximately 91% of the single-family permits issued between 2012 and 2014. The number of permits for each CSA/MSA was divided proportionally into the relevant counties of that CSA/MSA based on county population, giving each county a specific number of annual permits. All of these county assigned permits were then put into a CSA/MSA combined pool. The number of county permits matched the number of times that county was put into the combined pool. In other words, if a given county had 25 permits, that county was put into the combined pool 25 times; if the county had 1,000 permits, that county was put into the pool 1,000 times. Once all county assigned permits were put in the pool, 57 (91% of the required 63 data sets) were randomly selected. Each of these 57 represented a complete data set that was required to be collected from that county. Naturally, some counties were selected multiple times and some not selected at all. The remaining 6 data sets (9% of the permits) were randomly selected from the counties not included in the CSA/MSA combined pool. The Final Sampling Plan is included herein as Appendix 3.

Occasionally the required number of data sets could not be collected from a county due to overall lack of construction, lack of homes in the necessary state of completion, lack of builder cooperation, etc. In these instances an alternate county / jurisdiction was selected that had similar demographic characteristics to the original county / jurisdiction. Demographic characteristics used as selection criteria included Population, Number of Housing Units, Owner Occupancy Rate, Median Home Value, Education Level, Median Income, Poverty Level, and Density. Alternate counties used are identified on the Final Sampling Plan (Appendix 3).

Builder Recruitment

MEEA contracted with Verdatek to be the Data Collection Facilitator. The main focus of Verdatek's effort was to contact builders and jurisdictions identified in the sampling plan and gain agreement for data collector site access (builder recruitment). Verdatek has a wealth of experience with building energy efficiency, is well known across the state, and has strong connections with Missouri Home Builder Associations (HBA's).

In order to recruit builders, Verdatek would first call the code officials and HBA's in the counties to be sampled. Verdatek would explain the intent of the study, the logistics of the data collection process, the fact that all collected data would be anonymous, and determine if there were any homes currently being built in the area. If there were homes being built in the area, Verdatek would ask for builder contact information. Verdatek would then contact the builders, explain the program and ask if the builder was willing to participate. Occasionally, Verdatek would also directly contact builders in the sampling plan counties, without going through the code officials or HBA's. Verdatek then assembled a list of homes / builders willing to participate in the study for each county to be sampled and passed it on to the data collectors. The intent was to have Verdatek line up potential homes / builders no more than two weeks ahead of Cadmus being on site. This quick response process required frequent communication between Cadmus, Verdatek, and MEEA.

Once the data collectors had the county list from Verdatek, they would then contact the builders directly to make specific arrangements for a site visit. Typically the builders and sub-contractors that were on site at the time of the data collection effort were very cooperative but did not take an active interest in the data collection effort. It should be noted that many of the identified buildings were part of a subdivision, as opposed to a single home being constructed on an individual lot. This proved to be of great benefit to the data collectors since if the identified building was not at the necessary stage of construction, there was often a similar building in the subdivision the data collectors could use.

There were a few instances where no suitable buildings could be identified ahead of time for a given county. In these cases the data collection contractor generally had success by going to the county, finding buildings under construction and simply asking the builder for permission to survey the site. This reduced the time lost in traveling to sites that were not ready to be inspected or where the builder refused access. Travel time is one of the major sources of expenditures and minimizing it helped keep the project under budget.

As noted above, the Data Collection Facilitator is a builder, a former building official, and a well-known individual throughout the Missouri network of builders and Home Builder Associations. This was of two-fold benefit – he had the local experience and knowledge necessary to effectively communicate the intent of the program, and was also a known and respected individual in the building community across the state. He was able to build trust among builders and jurisdictions, while communicating the intent of the study effectively. We feel that these two qualities, along with the high proportion of subdivisions, were a significant part of the reason for the effectiveness of the builder recruitment effort.

Data Collection – General

The sampling plan had 4 regional groupings of counties; St. Louis metro, Kansas City metro, Southwest Missouri and Southeast Missouri. The data collection effort began by focusing on the parts of the state with greatest number of data sets first (the St. Louis metro area, followed by Kansas City metro) and then moving to Southwest and Southeast Missouri, and finally completing the other parts of the state and alternate counties.

The single visit protocol, as noted above, prevented all data being collected from a single home. In order to maximize efficiency, data collection was conducted either at the insulation stage or at final inspection. Data collection was typically performed by teams of two people who would rotate approximately every two weeks. The data collectors started field work in early April and completed the field data collection in mid-June. On-site data collection took approximately 30-45 minutes at the insulation stage and 45-60 minutes at final due to the use of diagnostic equipment such as a blower door and duct blaster. All data was recorded in data collection sheet.

Data sheets were completed and sent back to the Cadmus Idaho office from the field. After performing a review of the data for quality assurance, Cadmus sent the data sheets to MEEA, and MEEA reviewed and uploaded the data into the PNNL online portal. It took approximately 15 minutes to enter and upload the data collection form from a single site visit into the PNNL portal, and 127 forms were uploaded.

Insulation Inspection

The following information was typically collected when the house was at the insulation stage:

- Exterior wall insulation R-value and quality
- Foundation wall insulation R-value and quality
- Raised floor insulation R-value and quality
- Air sealing. This included inspecting for appropriate air sealing on all penetrations in the building envelope including around windows, plumbing penetrations, utility penetrations, etc.
- Duct insulation R-value
- Window efficiency (U-factor)
- Window Solar Heat Gain Coefficient (SHGC)
- Air handler system information such as size and efficiency (e.g. furnace or heat pump)

Upon entering a house at the insulation stage, one field member would document the HVAC information and determine total square footage. The other field member would collect the other available information, including using the RESNET standards for grading the quality of insulation installation, documenting all of the air-sealing measures, and noting window U-factor. In addition, any other energy efficiency information observed was documented on the checklist.

Final Inspection

The following information was typically collected when the house was at the final stage:

- Ceiling insulation R-value and quality
- High efficacy lighting[2]
- Envelope tightness (ACH50)
- Duct Leakage
- Additional information on the air handler and cooling system sizes

[2] Data collectors used ballast discriminators, which can identify LED high efficacy lighting (by determining if an electronic ballast is being used) without requiring that the bulb be removed from the fixture.

- Other efficiency features that could not be viewed at insulation stage that were part of the energy code. For example, this would include, but is not limited to, thermostats, water heater type, basement wall insulation that was not installed at insulation, etc.

Upon entering a house at the final inspection stage, one member would determine house dimensions and volume. The other field team member prepared the home for diagnostic testing and conducted a single point house pressurization test at 50 Pa and a single point depressurization duct leakage test at 25 Pa. When both these tasks were completed, this team member would collect any additional efficiency information observable at the time of the site visit – for example, information on water heater types and ventilation systems, and verifying that high efficacy lighting was installed and determining the type using ballast discriminators.

Quality Assurance

All data was collected on the appropriate data collection forms (books). One book was completed for each home that was visited. After the data was collected, Cadmus reviewed the data books looking for irregularities and discrepancies. If any arose, they would reach out to the performing field team in order to clarify values. Cadmus also worked with MEEA to resolve any follow-up questions from the project team pertaining to the data. The data books were then scanned and submitted to MEEA which did its own review of the data. MEEA then inputted all data into PNNL's RCD portal so that PNNL can run a full analysis of the findings.

Deliverables

In the contract executed between DED/DE and MEEA in March 2016, MEEA agreed to complete the following eight deliverables:

1. ### Provide overall project management and subcontract administration

   MEEA provided project management through coordinating weekly calls with subcontractors, planning agendas and presentation slides for two stakeholder meetings, and communicating offline with all subcontractors to ensure data collection proceeded on schedule and within the project budget.

2. ### Hire subcontractors to conduct the data collection study that is designed and completed in accordance with prescribed US DOE methodology

   MEEA hired Cadmus as the field data collection subcontractor. Cadmus has significant data collection experience from past construction baseline studies and is familiar with US DOE methodology. Because MEEA and Cadmus previously conducted a study in Kentucky in accordance with this US DOE methodology, the initial learning curve of understanding the methodology had already been overcome by the time the Missouri data collection study began.

   MEEA also hired Matt Belcher of Verdatek Solutions to conduct builder and jurisdiction outreach for the Missouri data collection study. Matt Belcher has decades of experience as a builder and code official in Missouri, as well as a large network of contacts in the Missouri homebuilding industry through his engagement in Home Builders Associations.

3. ### Contract for the data collection study using a formal written contract that is negotiated and executed with a qualified vendor
   MEEA wrote, negotiated, and executed formal written contracts with Verdatek Solutions and Cadmus as subcontractors for the Missouri data collection study.

4. ### Conduct the data collection study using the selected third-party vendor in accordance with the US DOE prescribed methodology
   MEEA conducted the data collection study according to US DOE methodology which included the development of a statewide sampling plan and in partnership with DED/DE, Cadmus, and Verdatek. Please see the "Methodology" section above for details on the data collection process, and the "Patterns of Non-Compliance" and "Patterns of Compliance" sections below for a summary of findings.

5. ### Manage collection of required data from sample homes
   MEEA managed the collection of required data from homes throughout the project by facilitating weekly phone calls, making decisions regarding sampling plan changes, coordinating stakeholder meetings, and communicating with DED/DE and subcontractors outside of weekly calls as needed. MEEA also archived copies of the completed data collection sheets and created a spreadsheet containing all collected data. Finally, MEEA inputted the data into the RCD to enable analysis by PNNL

6. ### Submit quarterly and final reports as required
   MEEA completed all required reporting, including two quarterly progress reports and a final report. Upon receipt of PNNL's analysis, MEEA will provide DED/DE an addendum to the final report which will include the results of PNNL's analysis.

7. ### Comply with the DED/DE General Terms and Conditions for Federal Subgrants
   MEEA complied.

8. ### Comply with the State of Missouri Division of Purchasing Terms and Conditions
   MEEA complied.

Stakeholder Meetings

The Project Team held two stakeholder meetings over the course of this project.

The first stakeholder meeting occurred on March 29, 2016 in Columbia Missouri, and the purpose of the meeting was twofold: to introduce key stakeholders to the study, and to communicate the intent of the study to builders and jurisdictions in order to collect data more efficiently. MEEA shared the goals and rationale of the study, shared results from the Kentucky code compliance study, and shared the preliminary sampling plan for Missouri. Cadmus and Verdatek answered questions and shared

information about their data collection processes. 20 people attended this meeting (including members of the Project Team).

The second stakeholder meeting occurred on June 1, 2016 in Columbia Missouri, with a remote call-in option. The purpose of this meeting was to share an update on statewide data collection, provide an overview of preliminary results, share updates to the sampling plan, and discuss opportunities for future collaboration. 12 people attended this meeting in person, and 6 people attended using the webinar option.

Upon receipt of the PNNL analysis, MEEA will hold a final stakeholder meeting to share the results with the stakeholder group and discuss potential next steps. It is anticipated that the final meeting will be held in September, 2016 (depending on when PNNL results are received). As with previous meetings, MEEA and DED/DE will provide advanced notice to stakeholders of the meeting time and place.

Results: Patterns of Non-Compliance[3]

The field teams found 5 code requirements that consistently did not comply with 2009 IECC requirements:

- Duct Leakage
- Duct Sealing
- Exterior Wall Insulation Installation Quality
- High Efficacy Lights
- Basement Wall Insulation

Duct Leakage

All ducts were tested regardless of whether or not they were in conditioned space. The 2009 IECC allows a maximum of 12 cfm/100ft^2 @25Pa total leakage for ducts in unconditioned space when tested during the post construction phase. 50% of the ducts located in unconditioned spaces did not meet this requirement.

Duct Sealing

93% of ducts located in conditioned space had leakage rates over 12 cfm/100ft^2@25Pa. At times, these ducts were too leaky for the equipment to transmit a reading. While there is no code required maximum leakage requirement for ducts in conditioned space, they are required to be sealed. Clearly these ducts are not meeting the sealing requirement. Following are some of the observed problems with respect to duct sealing:

- Unsealed joints and seams on the main trunks
- Unsealed joints and seams of air handlers
- Unsealed filter boxes
- Unsealed return chases

[3] Because of the need to calculate the heating/cooling loads from the data provided, HVAC sizing data is not yet available.

Return Chases

Using framing members as return ducts greatly impacts the leakage levels. The leakage is typically severe enough to disrupt the load distributions that the HVAC system was designed around. Disrupting the load distribution can lead to a large variety of problems including: poor indoor air quality, moisture entering the thermal envelope, and air handler inefficiencies.

Exterior Wall Insulation Installation Quality

75% of the insulation installed in the exterior walls was quality grade 2 or 3 (with grade 1 being the highest quality). While the wall insulation R-values all met or exceeded the 2009 IECC, the quality of the installation has a significant impact on the effective R-value. Training on how to install insulation so that it meets quality grade 1 would likely result in energy savings opportunities in new homes.[4]

High Efficacy Lights

67% of the houses observed had no high efficacy lights installed, while 94% of the homes did not meet the code required minimum of 50% high efficacy lights.

Basement Wall Insulation

Of the 70 homes in the data set that had observable basement insulation, 49 of them (70%) had no insulation installed in basement walls. This finding was surprising to the data collection team and represents a substantial energy-saving opportunity. Further research will be needed to understand why builders are opting not to insulate basements – for example, reviewing basement insulation requirements in local building codes and whether those requirements have been removed or amended. Training and education on basement wall insulation could be an important component of future strategies to save energy in new homes.

Results: Patterns of Compliance

The field team found several code requirements that consistently complied with 2009 IECC requirements:

- Air Sealing
- Exterior Wall Insulation R-Values
- Ceiling Insulation Quality

Air Sealing

Of the 63 blower door tests conducted, only two homes did not meet the 2009 IECC requirement of 7 ACH50. The other 61 blower door data points collected meet the 2009 IECC requirement, including two homes that are under 3 ACH50.

Exterior Wall Insulation R-Values

One hundred percent of homes in this study met the 2009 IECC requirement of having R-13 or greater insulation installed in exterior walls.

[4] https://www.resnet.us/uploads/documents/conference/2012/pdfs/Cottrell-RESNET_Insulation_Grading_Criteria.pdf

Ceiling Insulation Quality

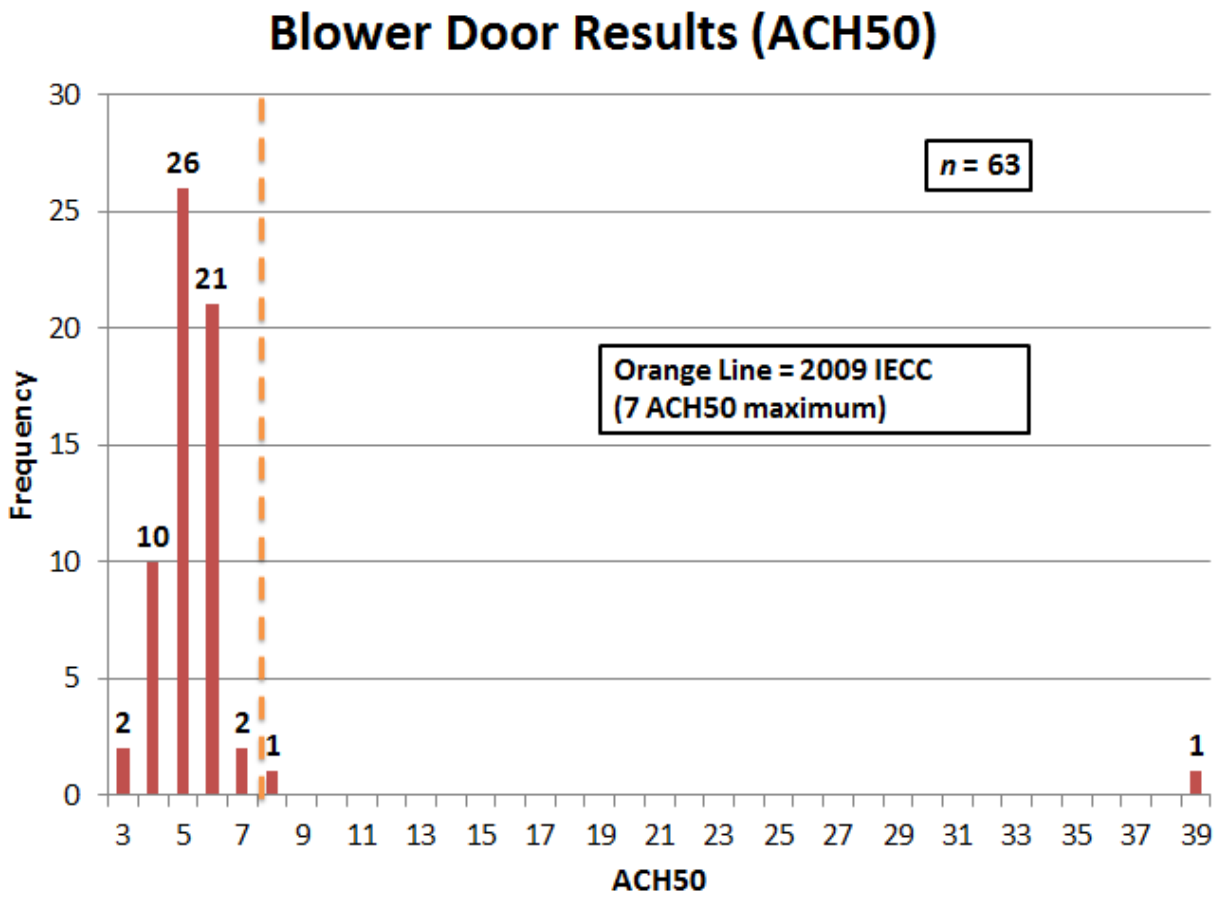
87% of the insulation installed in attics and roofs was quality grade 1 – the highest quality. The other 13% of ceiling insulation data points were quality level 2, and there were no instances of finding quality level 3 insulation in ceilings and attics across the state.

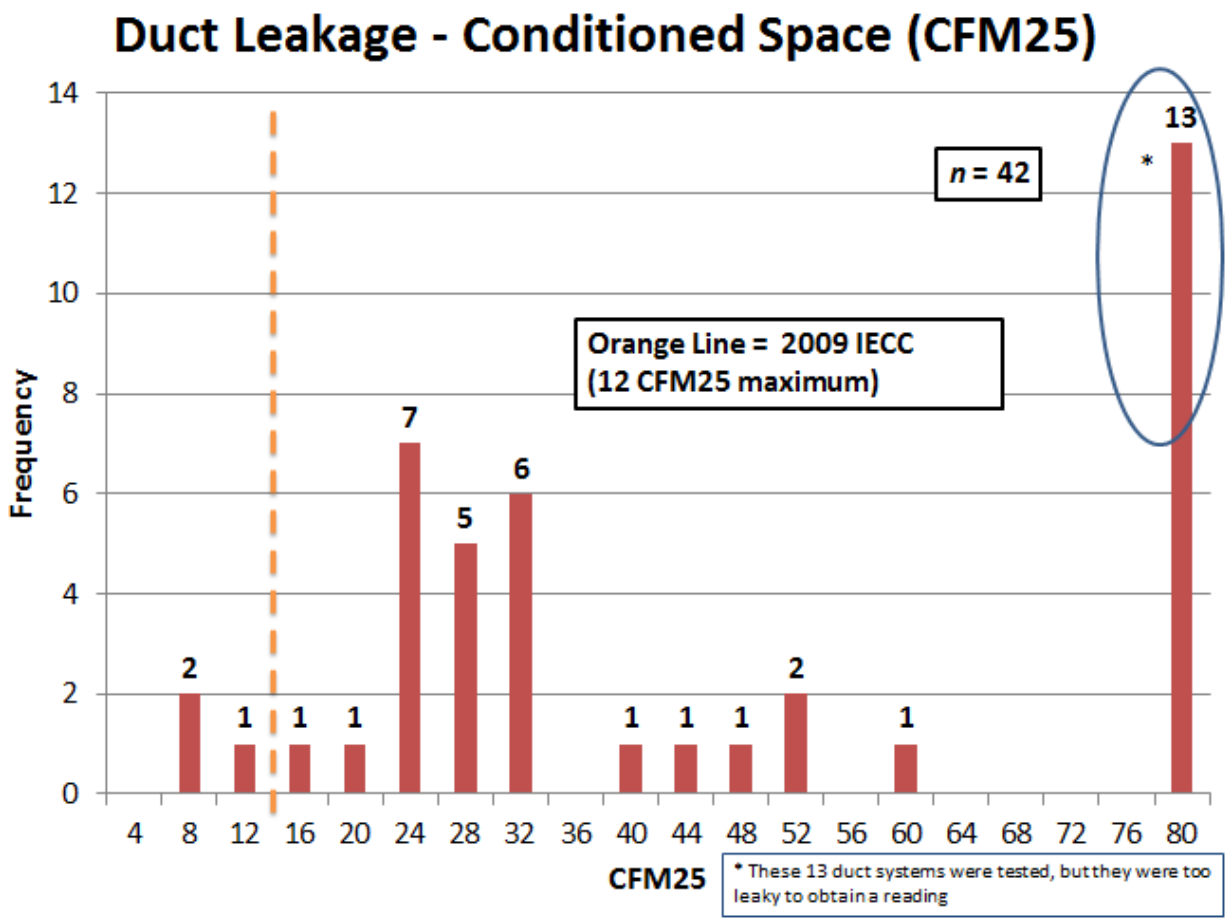
Expenditure of Grant Funds

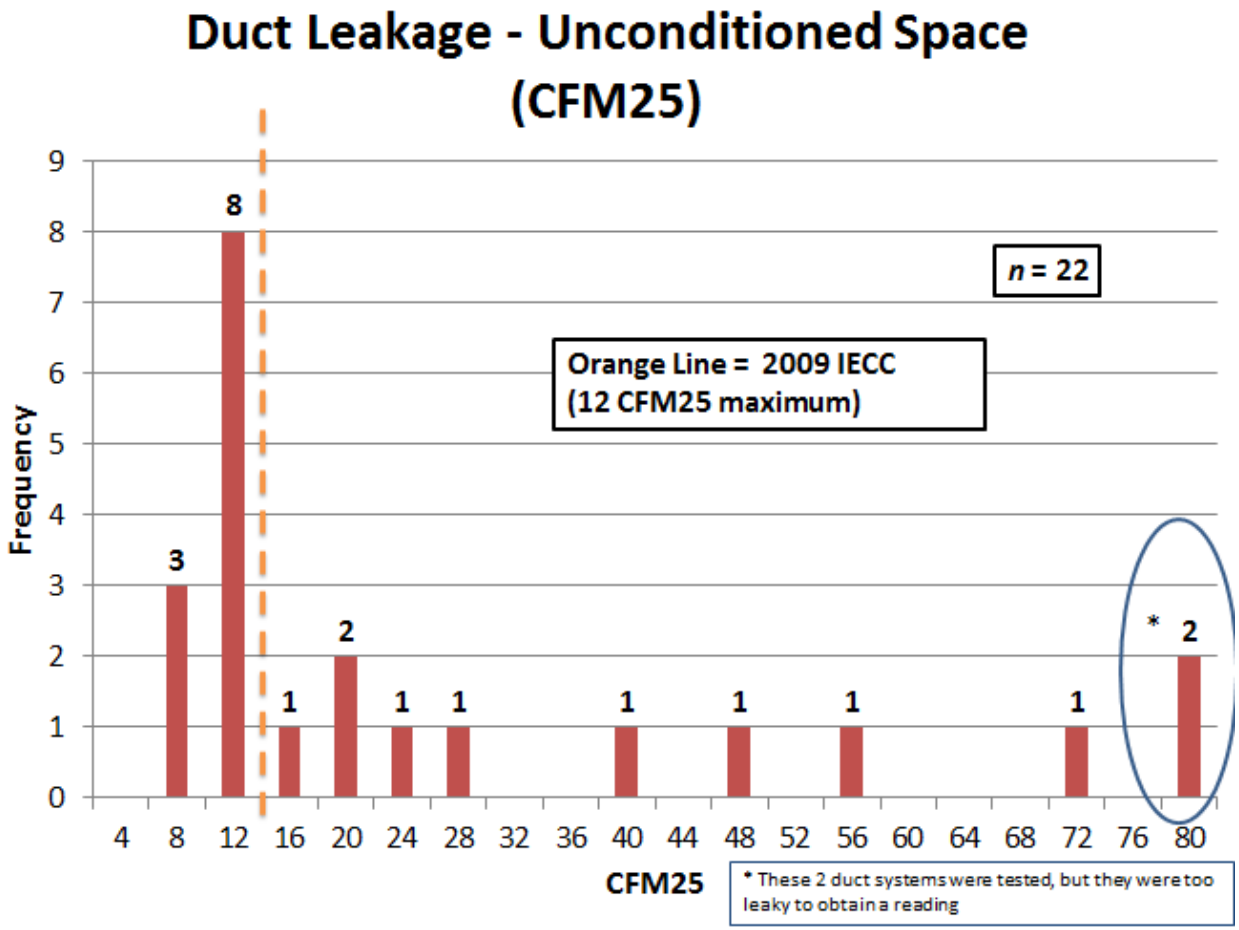
The expenditure of grant funds is summarized in the following chart:

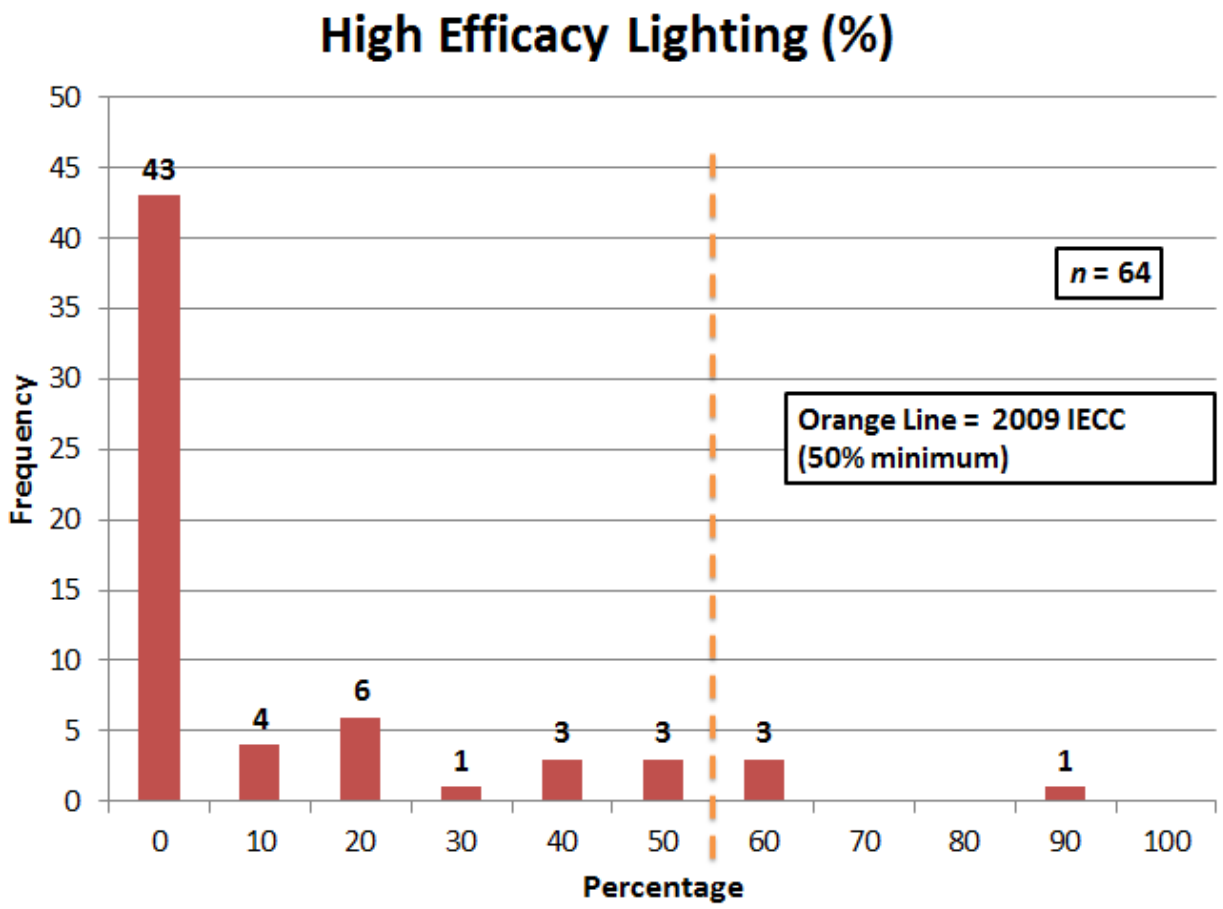
COST CATEGORY	CURRENT PERIOD EXPENSE	YEAR ONE EXPENSE	YEAR TWO EXPENSE	CUMULATIVE GRANT EXPENSE	LINE ITEM BUDGETED AMOUNT	REMAINING BUDGET AMOUNT
I. PERSONNEL COSTS						
01 Task (MEEA Personnel)	$7,026.05	$5,088.24	$0.00	$12,114.29	$12,114.29	$0.00
02 Task	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
03 Task	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
4	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
5	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
6	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
07 Fringe	$1,756.51	$1,272.06	$0.00	$3,028.57	$3,028.57	$0.00
Total Personnel Costs	**$8,782.56**	**$6,360.30**	**$0.00**	**$15,142.86**	**$15,142.86**	**$0.00**
II. OTHER EXPENSES						
01 Travel	$0.00	$1,000.00	$0.00	$1,000.00	$1,000.00	$0.00
02 Supplies	$128.45	$0.00	$0.00	$128.45	$128.45	$0.00
03 Contractual (Data Collection)	$95,635.80	$33,092.89	$0.00	$128,728.69	$128,728.69	$0.00
04 Contractual (Data Collection Facilitator)	$7,500.00	$7,500.00	$0.00	$15,000.00	$15,000.00	$0.00
Total Other Expenses	**$103,264.25**	**$41,592.89**	**$0.00**	**$144,857.14**	**$144,857.14**	**$0.00**
III. INDIRECT	**$0.00**	**$0.00**	**$0.00**	**$0.00**		
IV. TOTAL EXPENSES FOR REIMBURSEMENT	**$112,046.81**	**$47,953.19**	**$0.00**	**$160,000.00**	**$160,000.00**	**$0.00**
						Total $160,000

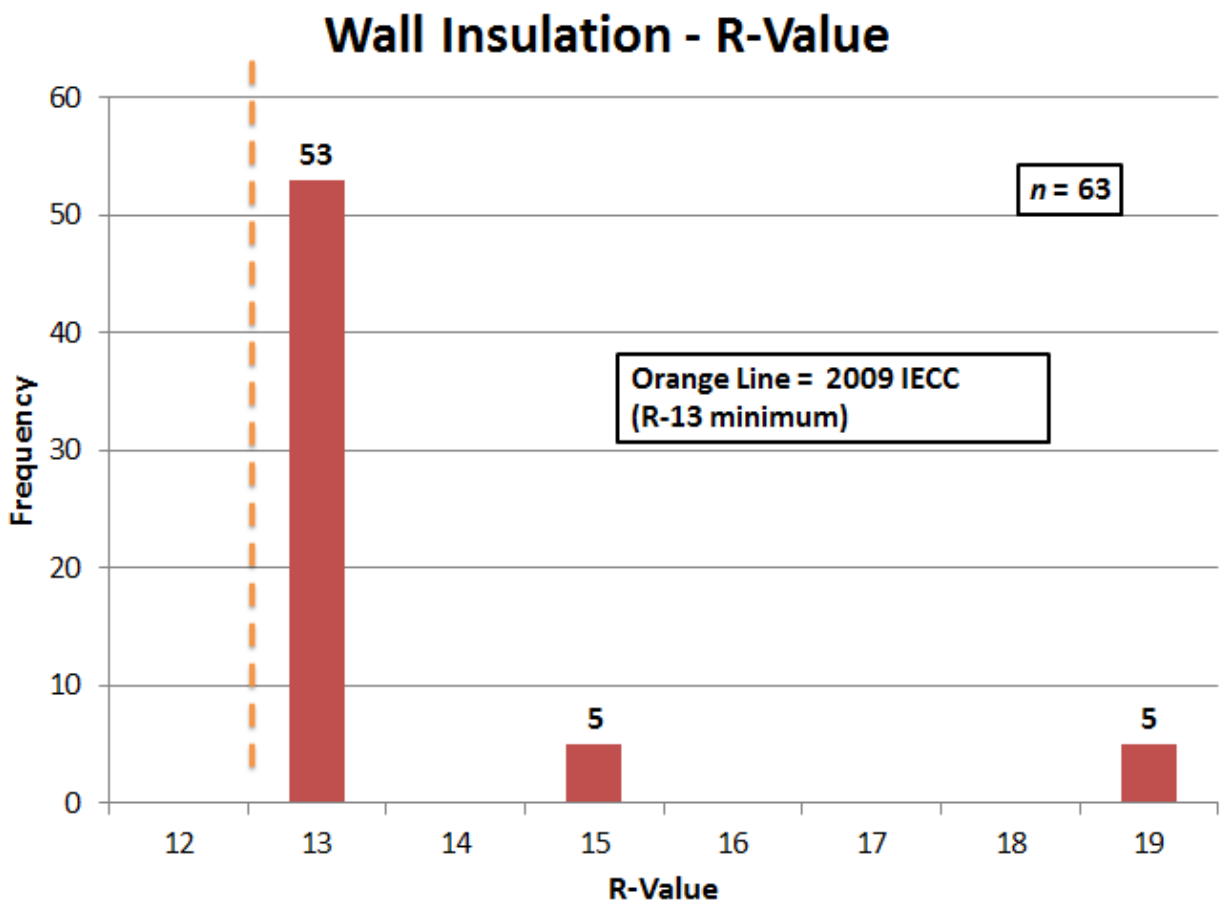
FINAL STATEWIDE DATA COLLECTION HISTOGRAMS

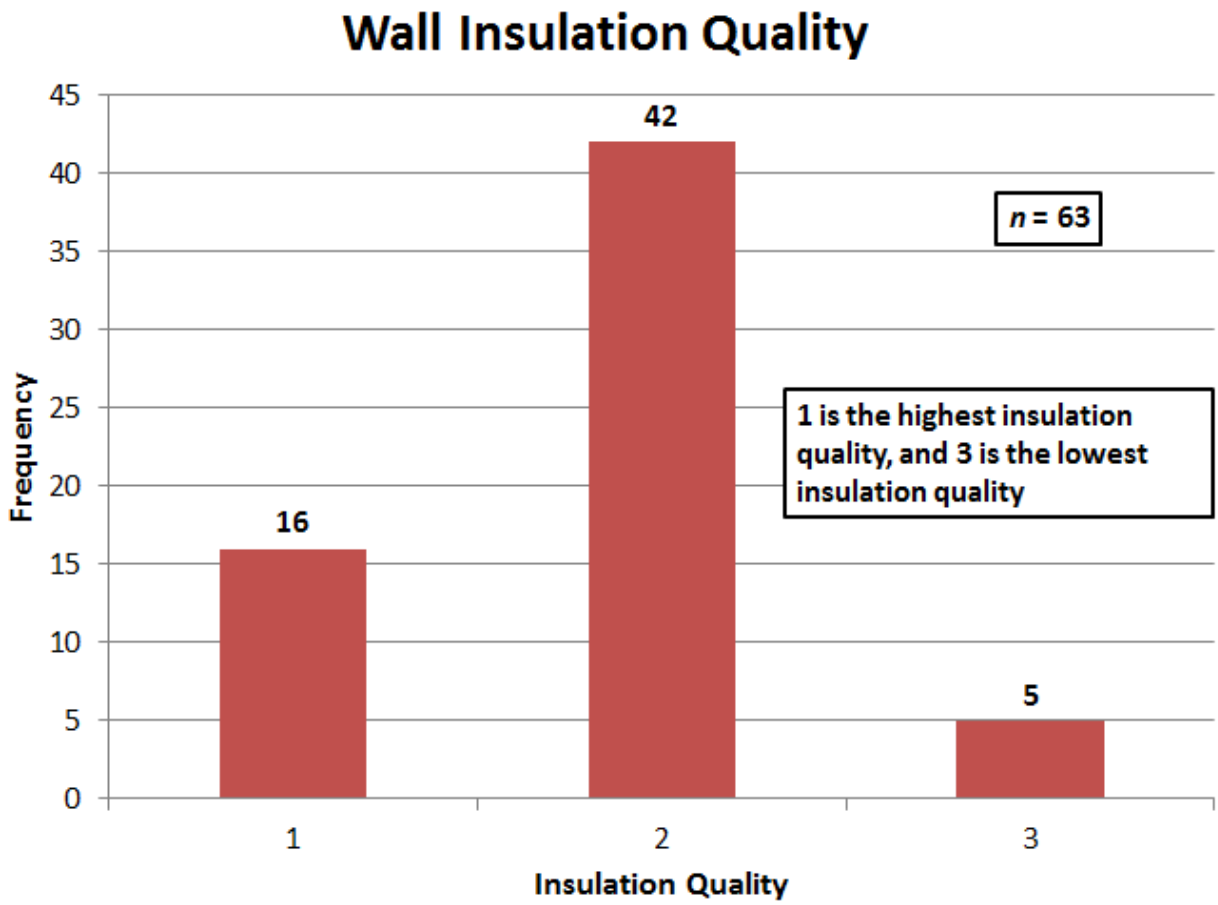

Blower Door Results (ACH50)
n = 63
Orange Line = 2009 IECC
(7 ACH50 maximum)
Frequency
ACH50
30
25
20
15
10
5
0
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
2
10
26
21
2
1
1

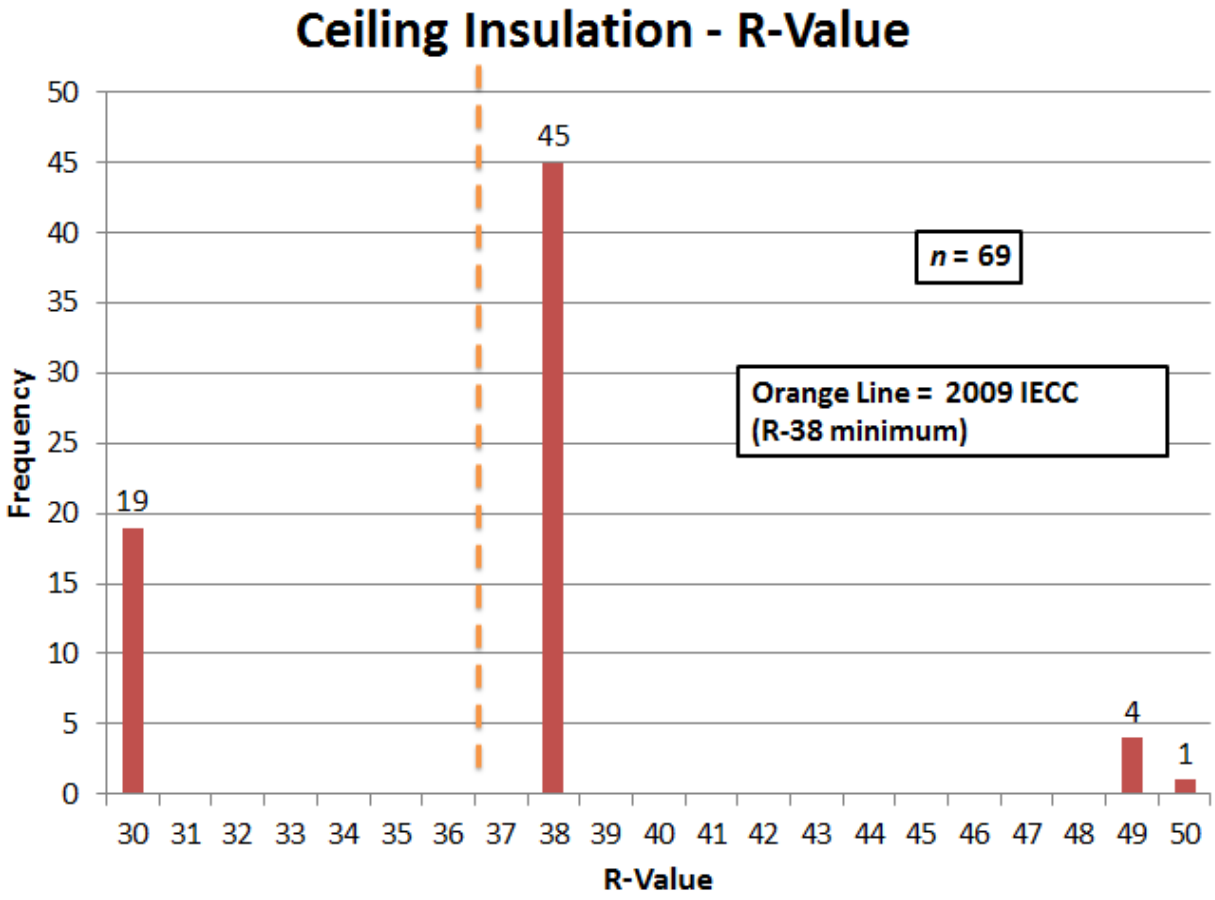

Duct Leakage - Conditioned Space (CFM25)
Frequency
CFM25
n = 42
Orange Line = 2009 IECC
(12 CFM25 maximum)
* These 13 duct systems were tested, but they were too leaky to obtain a reading
0
2
4
6
8
10
12
14
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
2
1
1
1
7
5
6
1
1
1
2
1
13
*

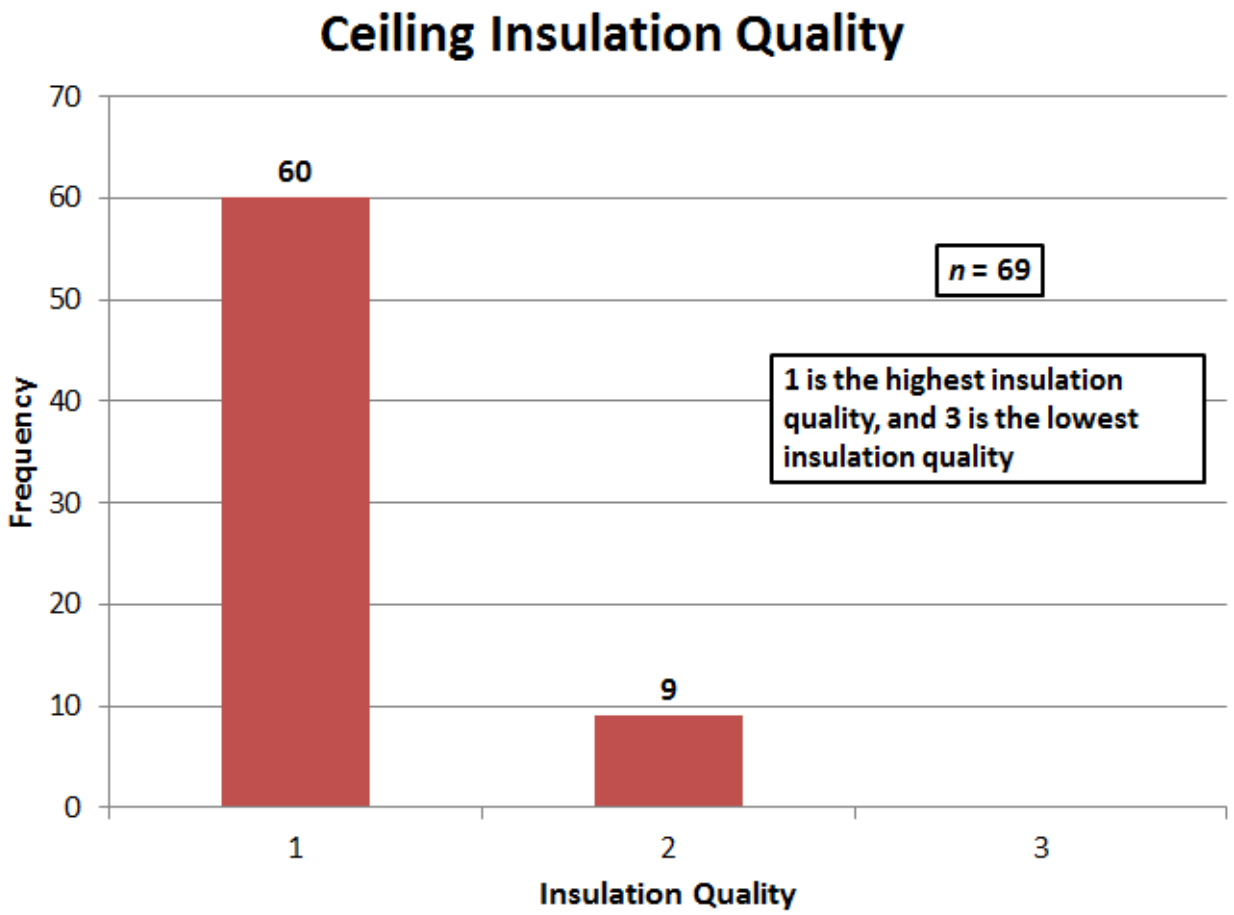

Duct Leakage - Unconditioned Space (CFM25)
Frequency
CFM25
n = 22
Orange Line = 2009 IECC (12 CFM25 maximum)
* These 2 duct systems were tested, but they were too leaky to obtain a reading
0
1
2
3
4
5
6
7
8
9
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
3
8
1
2
1
1
1
1
1
1
*
2

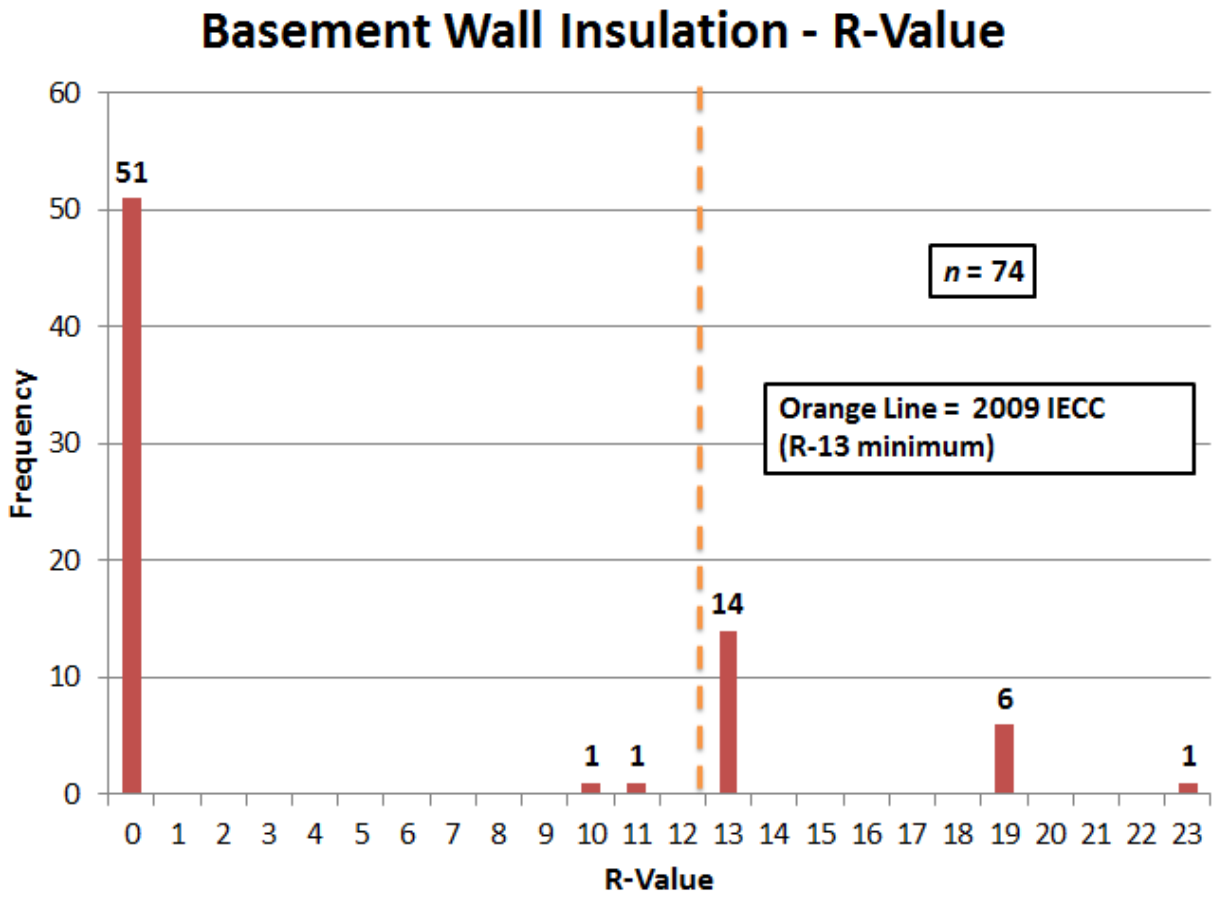

High Efficacy Lighting (%)
Frequency
Percentage
n = 64
Orange Line = 2009 IECC (50% minimum)
43
4
6
1
3
3
3
1
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45
50

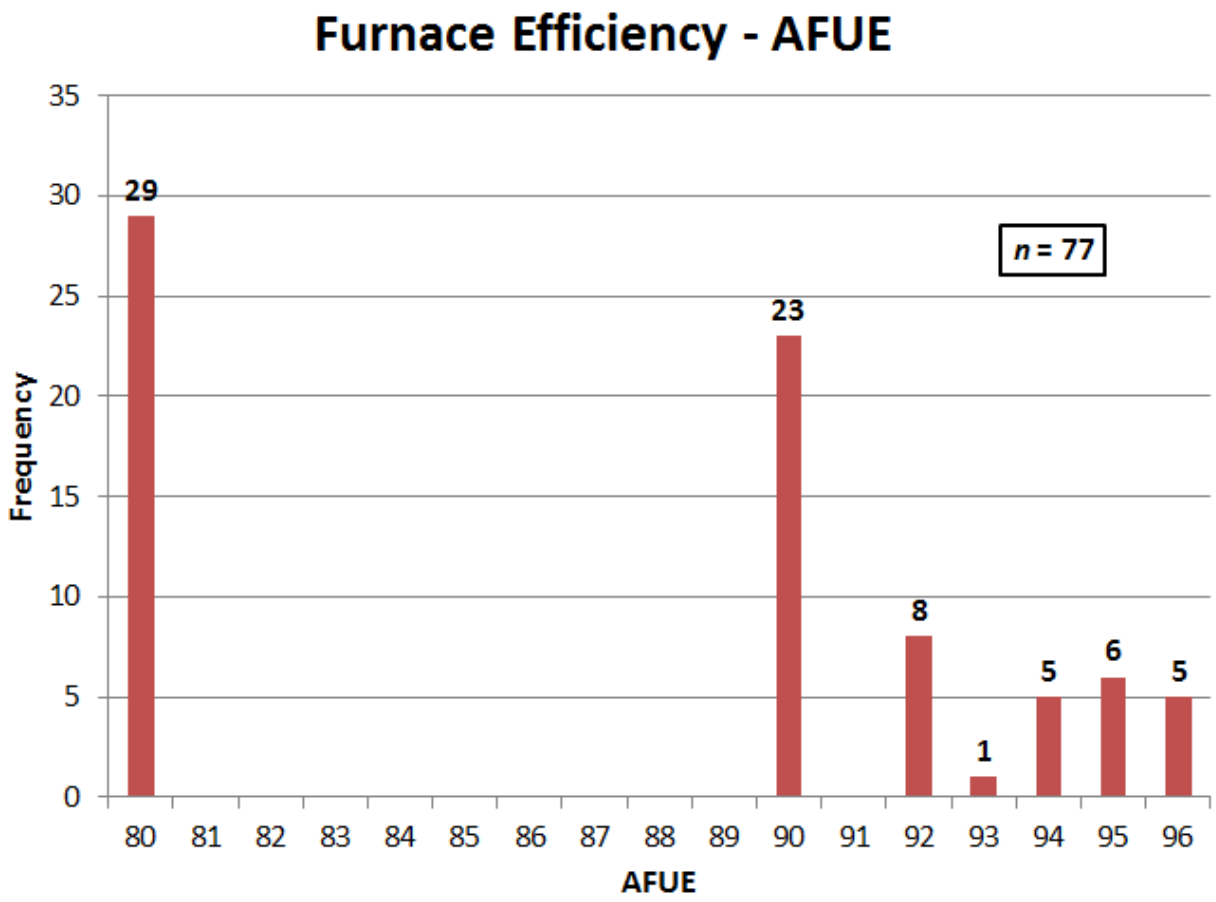

Wall Insulation - R-Value
60
50
40
30
20
10
0
Frequency
53
5
5
n = 63
Orange Line = 2009 IECC
(R-13 minimum)
12
13
14
15
16
17
18
19
R-Value

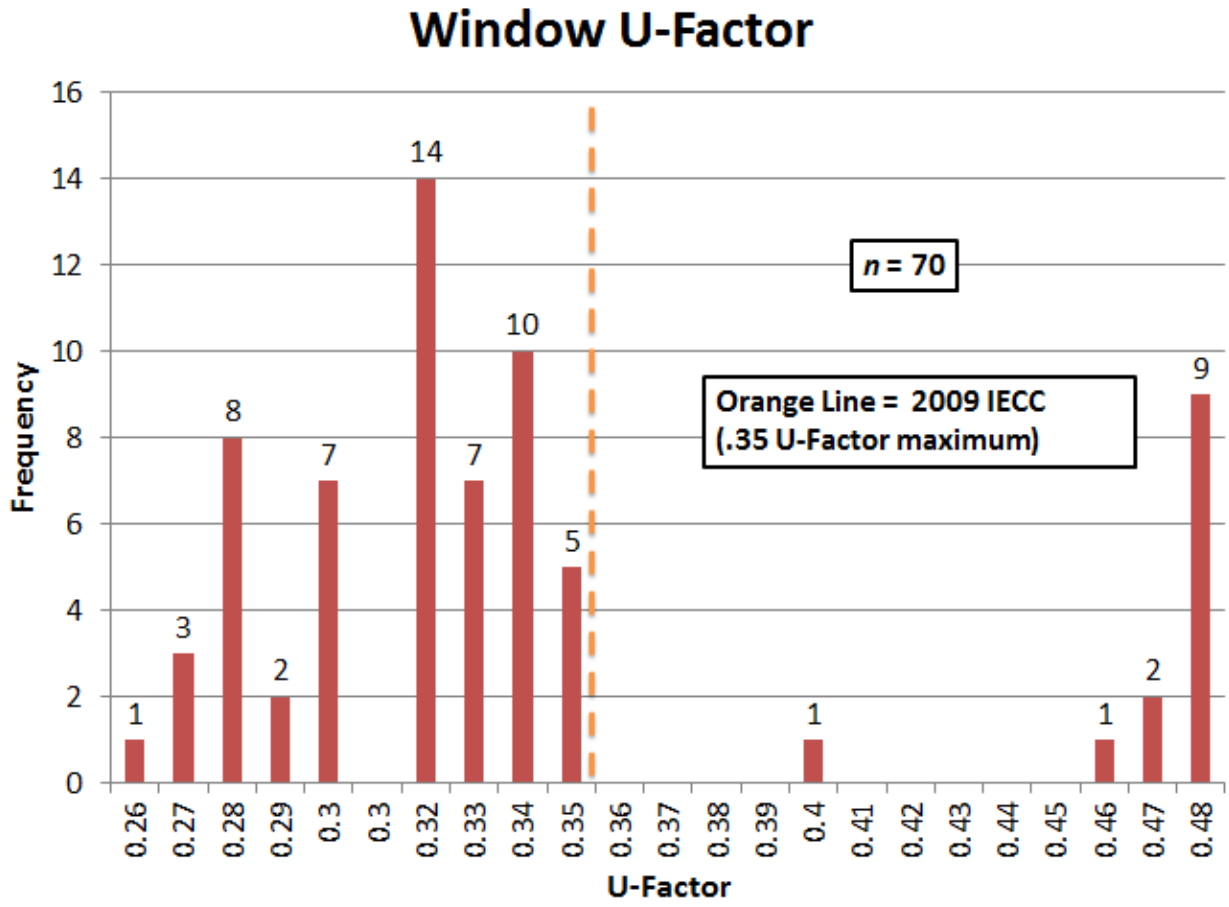

Wall Insulation Quality
45
40
35
30
25
20
15
10
5
0
Frequency
42
16
5
n = 63
1 is the highest insulation quality, and 3 is the lowest insulation quality
1
2
3
Insulation Quality


Ceiling Insulation - R-Value
Frequency
R-Value
n = 69
Orange Line = 2009 IECC
(R-38 minimum)
19
45
4
1
0
5
10
15
20
25
30
35
40
45
50
30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50


Ceiling Insulation Quality
70
60
50
40
30
20
10
0
Frequency
60
9
n = 69
1 is the highest insulation quality, and 3 is the lowest insulation quality
1
2
3
Insulation Quality


Basement Wall Insulation - R-Value
Frequency
R-Value
n = 74
Orange Line = 2009 IECC
(R-13 minimum)
51
1
1
14
6
1
0
10
20
30
40
50
60
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


Furnace Efficiency - AFUE
Frequency
AFUE
n = 77
29
23
8
1
5
6
5
0
5
10
15
20
25
30
35
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96


Window U-Factor
Frequency
U-Factor
n = 70
Orange Line = 2009 IECC
(.35 U-Factor maximum)
0
2
4
6
8
10
12
14
16
1
3
8
2
7
14
7
10
5
1
1
2
9
0.26
0.27
0.28
0.29
0.3
0.3
0.32
0.33
0.34
0.35
0.36
0.37
0.38
0.39
0.4
0.41
0.42
0.43
0.44
0.45
0.46
0.47
0.48

APPENDIX 1

Missouri Residential Building Energy Code Practices Study

Project Team Members

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- Peter Arathoon
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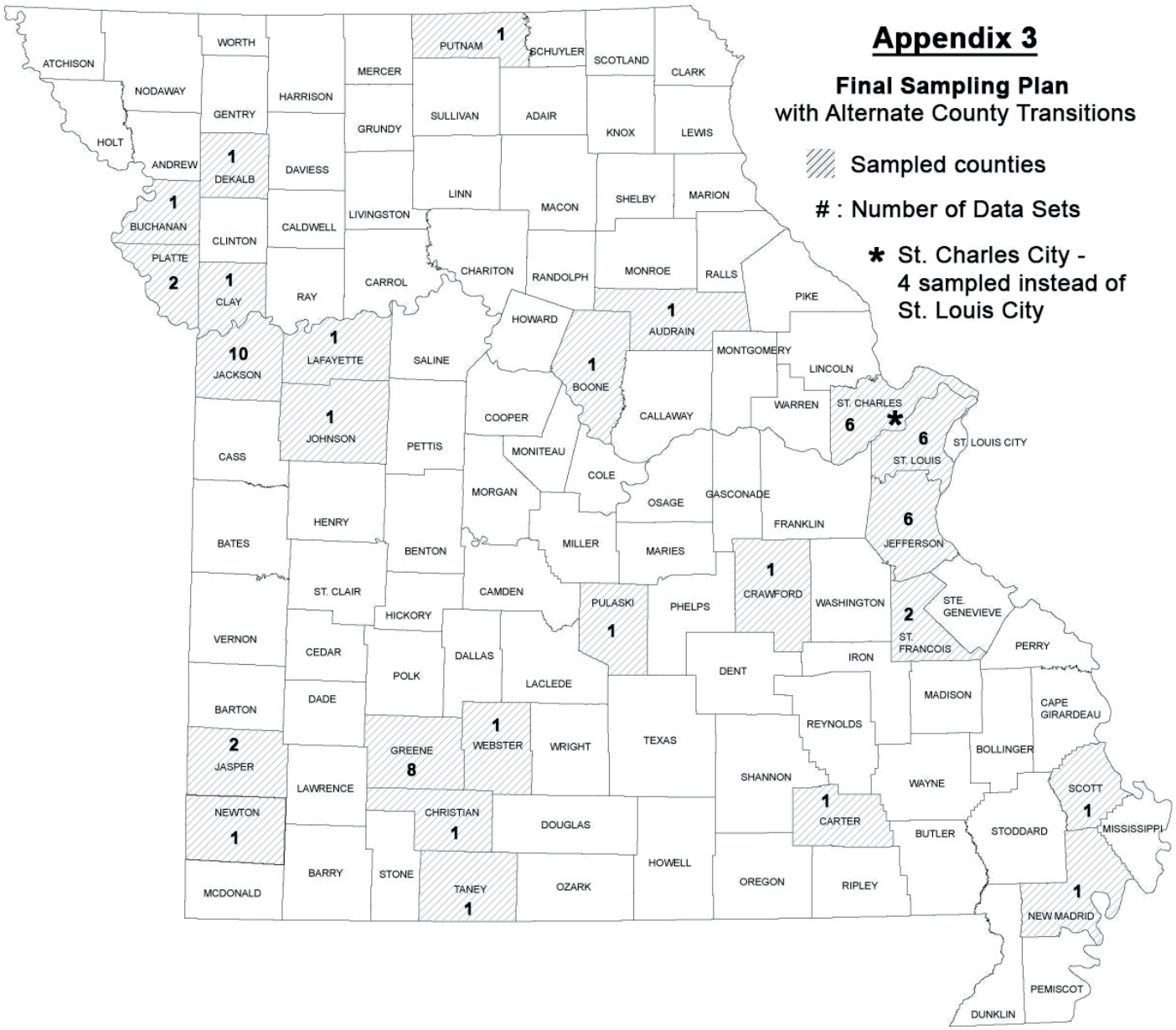
APPENDIX 2

Missouri Residential Energy Code Building Practices Study

Count of Key Item Observations

Topic	Number of Data Points
Key Item: Blower Door Test Results	63
Key Item: Window Solar Heat Gain Coefficient	70
Key Item: Window U-Factor	70
Key Item: Exterior Wall Insulation	63
Key Item: Ceiling Insulation	69
Key Item: Fraction of High-Efficacy Lighting	64
[5]Foundation Insulation - floor	13
Foundation Insulation - basement	70
Foundation Insulation - slab	2
Key Item: Total Foundation Insulation	85
Key Item: Duct Leakage Test Results	64

[5] Since there are different types of foundations used in residential construction, the DOE protocol allows that the required 63 foundation observations may be a mix of all types. The total number of foundation observations whether basement, crawl space or slab, must meet or exceed 63.

APPENDIX 3

Key Item Sampling Plan with Alternate County Transitions