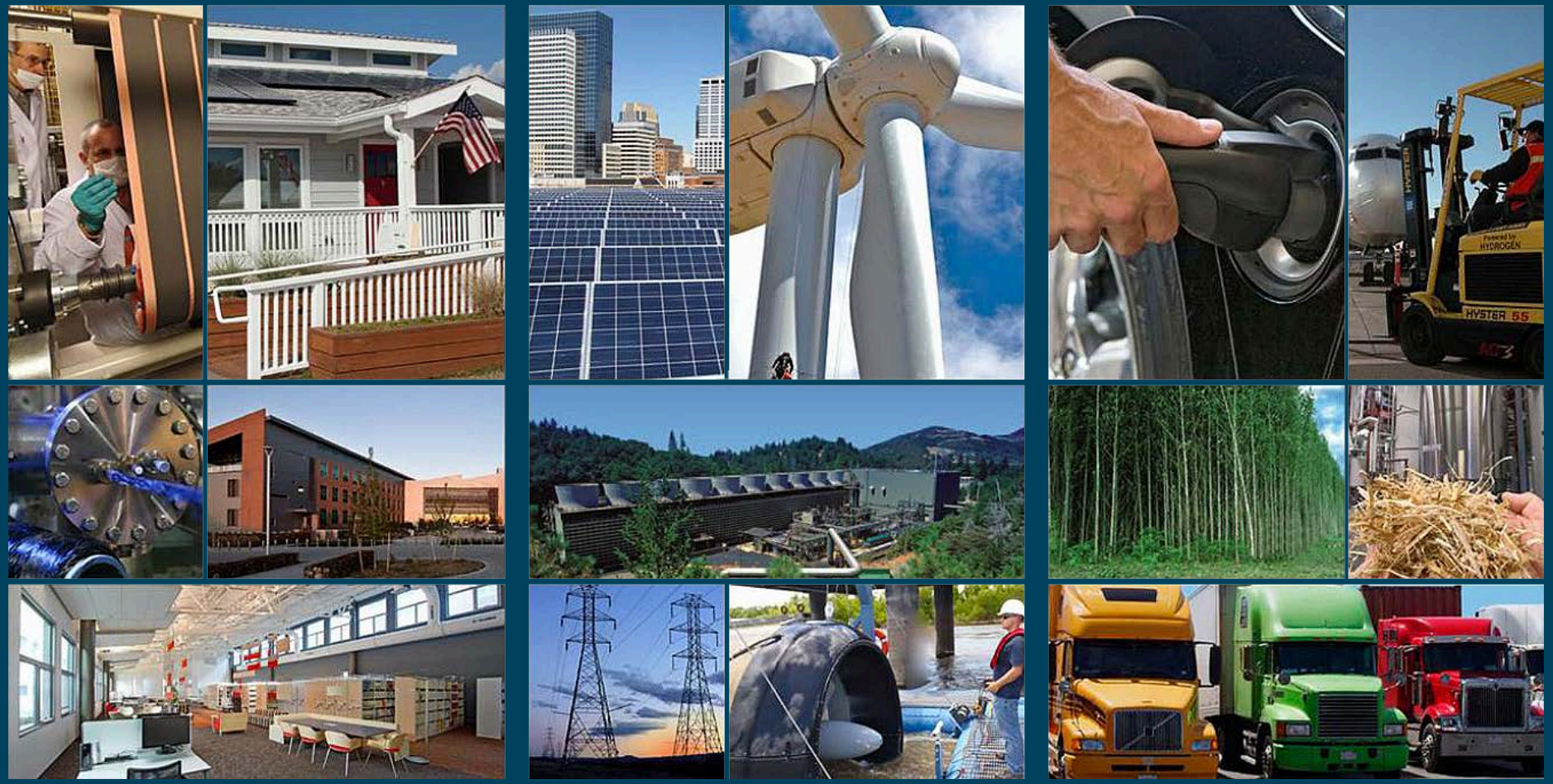
Building Energy Codes Program

Single Family Residential Energy Code Field Study



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

December 7, 2015

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Compliance ≠ Energy Savings

Project Organization

Three phases:

Year 1: Baseline field study

Years 2-3: Education and training using information from baseline study

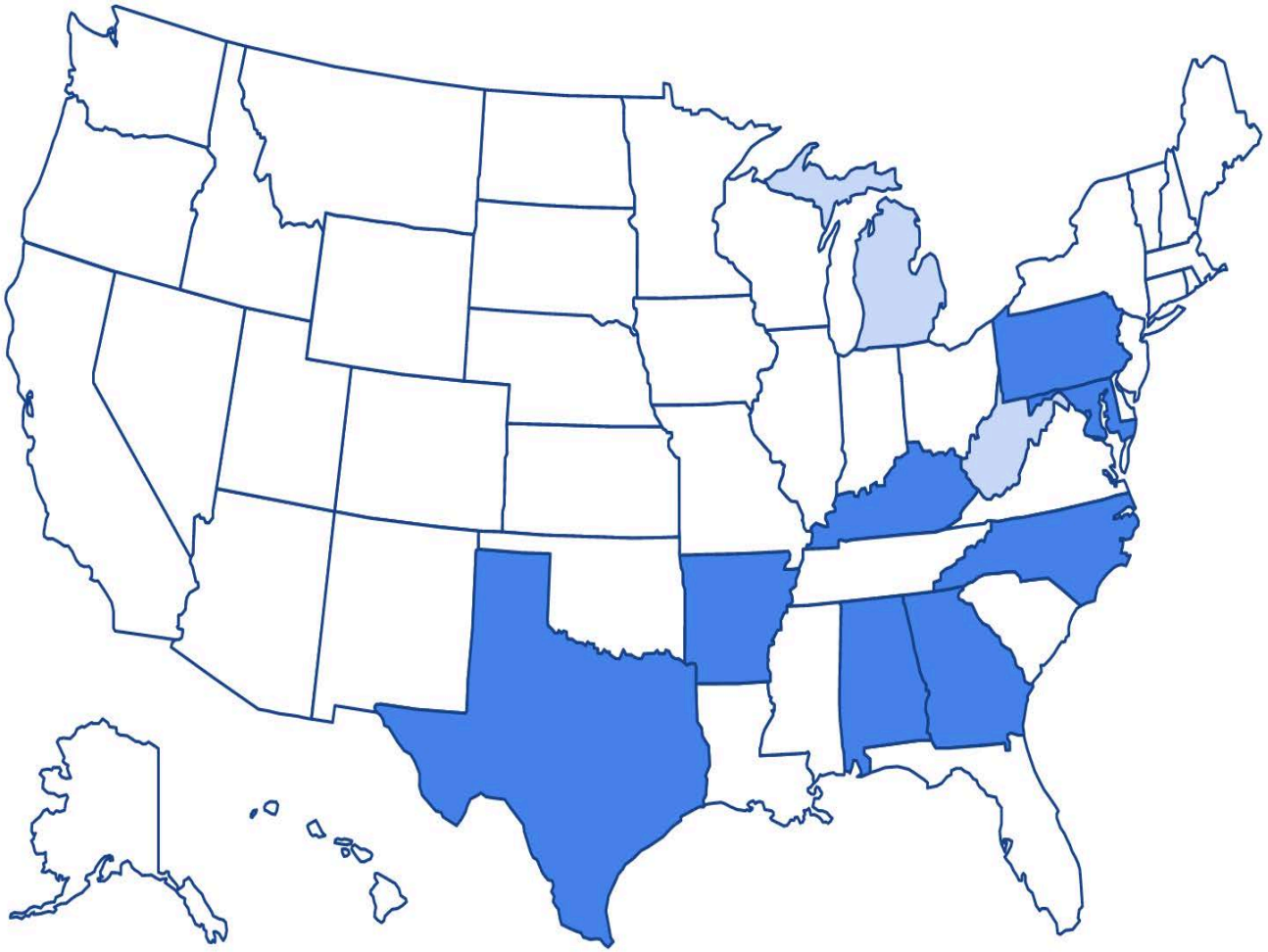
Year 4: Follow-up field study

Phase I Goal

Develop and test an energy-based methodology for energy code field studies.

1. Establish Energy Use Intensity (kBtu/sf/year) of code-regulated energy in single family homes in a state
2. Identify code requirements with high savings potential and low compliance to target with education and training
3. Calculate the potential energy, cost and emissions benefits from increased compliance with targeted requirements

Field Study States



DOE Overall Project Goals

1. Establish a national model methodology based on an Energy Use Intensity (EUI – kBtu/sf/year) metric

2. Establish a business case for private investment to increase energy code savings

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Ground Rules

- **Single family new construction** only
- **One visit** per home

Avoids influencing builder behavior

Insufficient data to determine compliance for a single home

- Code officials provide only addresses of qualifying homes
- Not present for onsite data collection
- Only **pre-occupancy** homes visited
- Only observed, installed measures counted – no assumptions
- No personally identifying information submitted to DOE or PNNL
- Findings valid only at **state level**
- Blower door & duct testing results shared with builders (upon request)

Sampling Approach

- **State-level sampling plan** assigns the number of observations to be collected from specified jurisdictions based on:
  - U.S. Census Bureau permit data
  - Average housing starts over past three years
- **Proportional random sample** = areas with more construction more heavily sampled
- **Plans validated through kickoff meetings**—stakeholder review & buy in is crucial
- Homes in sampled jurisdictions visited randomly
  - Selected from list of all homes by local building department
  - Homes visited until sampling plan is fulfilled



- PNNL identified *key* individual code requirements with largest energy impacts:
  - Envelope air tightness (ACH50)
  - Window SHGC & U-factor
  - Wall insulation (R-value)
  - Ceiling insulation (R-value)
  - Lighting (% HE lamps)
  - Foundation insulation (R-value)
  - Duct leakage



Sampling Approach (cont.)

- Estimated expected distribution (variance) of field observations
- Standard statistical formulas used to determine **63 observations** of EACH key item
  - Needed to detect statistically significant differences in pre- & post-studies
  - Enable statewide sampling plan & energy metric
  - Practical limitations requires going to many more than 63 homes

Data Collection

- Data collection forms customized for each state code & climate zone
  - Key items drive sampling & analysis
  - Information on *all* code requirements collected
- Some non-code requirements collected for verification & analysis purposes (e.g., foundation type, HVAC type, home size, etc.)
- Blower door & duct leakage testing performed wherever possible
- Insulation installation *quality* graded
- Quality assurance/control as part of handoff to PNNL

Results to Date

State	Project Lead	Baseline Code	Homes Visited	Data Collection Complete	EUI Analysis Done
AL	Institute for Market Transformation	2009 IECC	134	YES	YES
AR	Southeast Energy Efficiency Alliance	2009 IECC	181	In Progress	Waiting
GA	Southeast Energy Efficiency Alliance	2009 IECC	223	In Progress	Waiting
KY	Midwest Energy Efficiency Alliance	2009 IECC	140	YES	YES
MD	Maryland Energy Administration	2015 IECC	207	YES	YES
MI	Navigant	2009 IECC	124	YES	YES
NC	Appalachian State University	NC Code	249	YES	YES
PA	Performance Systems Development	2009 IECC	171	YES	YES
TX	National Association of State Energy Officials	2009 IECC	133	YES	YES
WV	Appalachian Residential Consortium for Energy Efficiency	2009 IECC	0	Not Started Yet	Waiting

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RESULTS

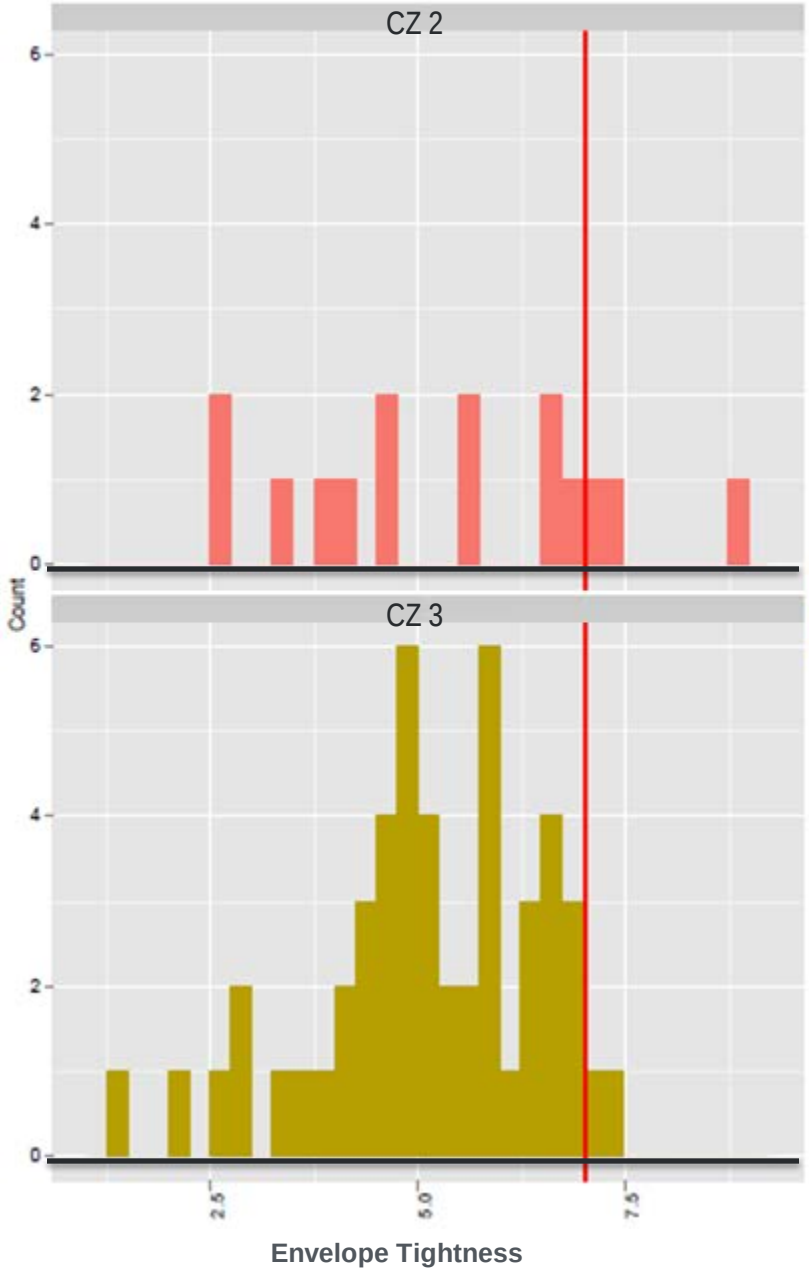
Initial Results Package

State Comparisons

Initial Results Package

- Illustrates typical “initial” results presentation provided to the state project teams after analysis is complete
  - Key Items
  - EUIs
  - Energy savings, cost savings and emission reductions potential

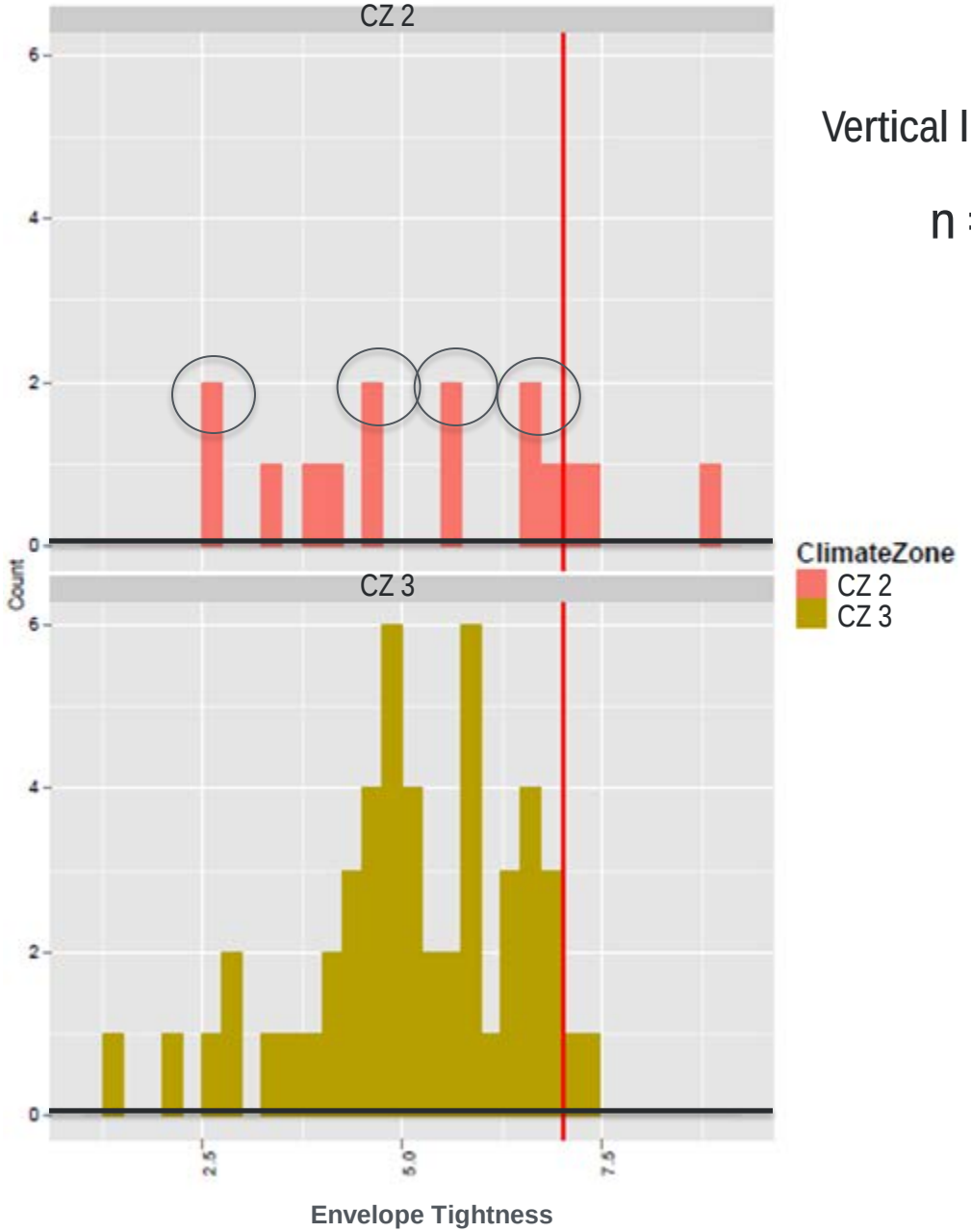
Envelope Tightness (ACH50) – Alabama



Vertical line = 2009 IECC Requirement

n = 65

Envelope Tightness (ACH50) – Alabama



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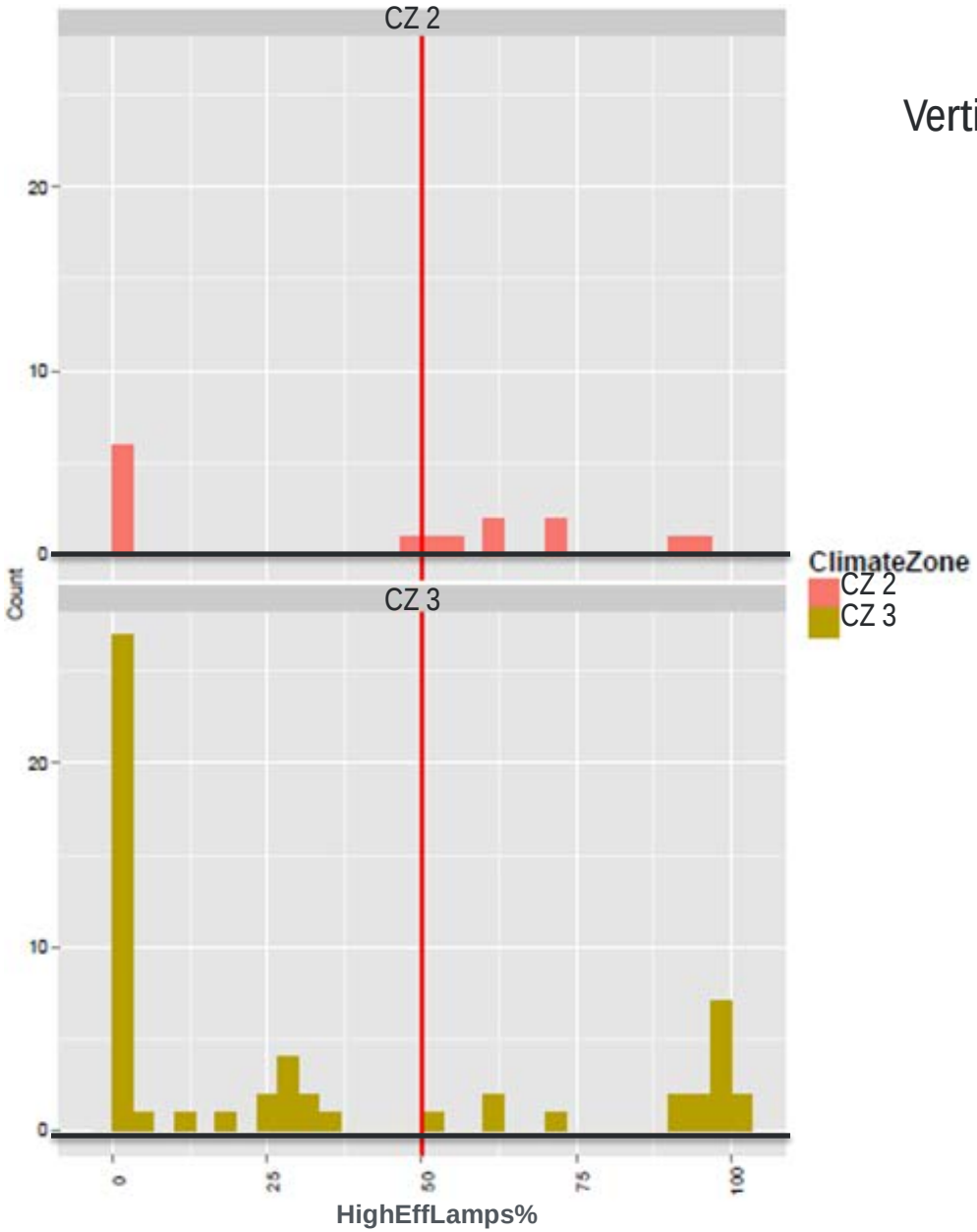
High Efficacy Lamps (%) – Alabama



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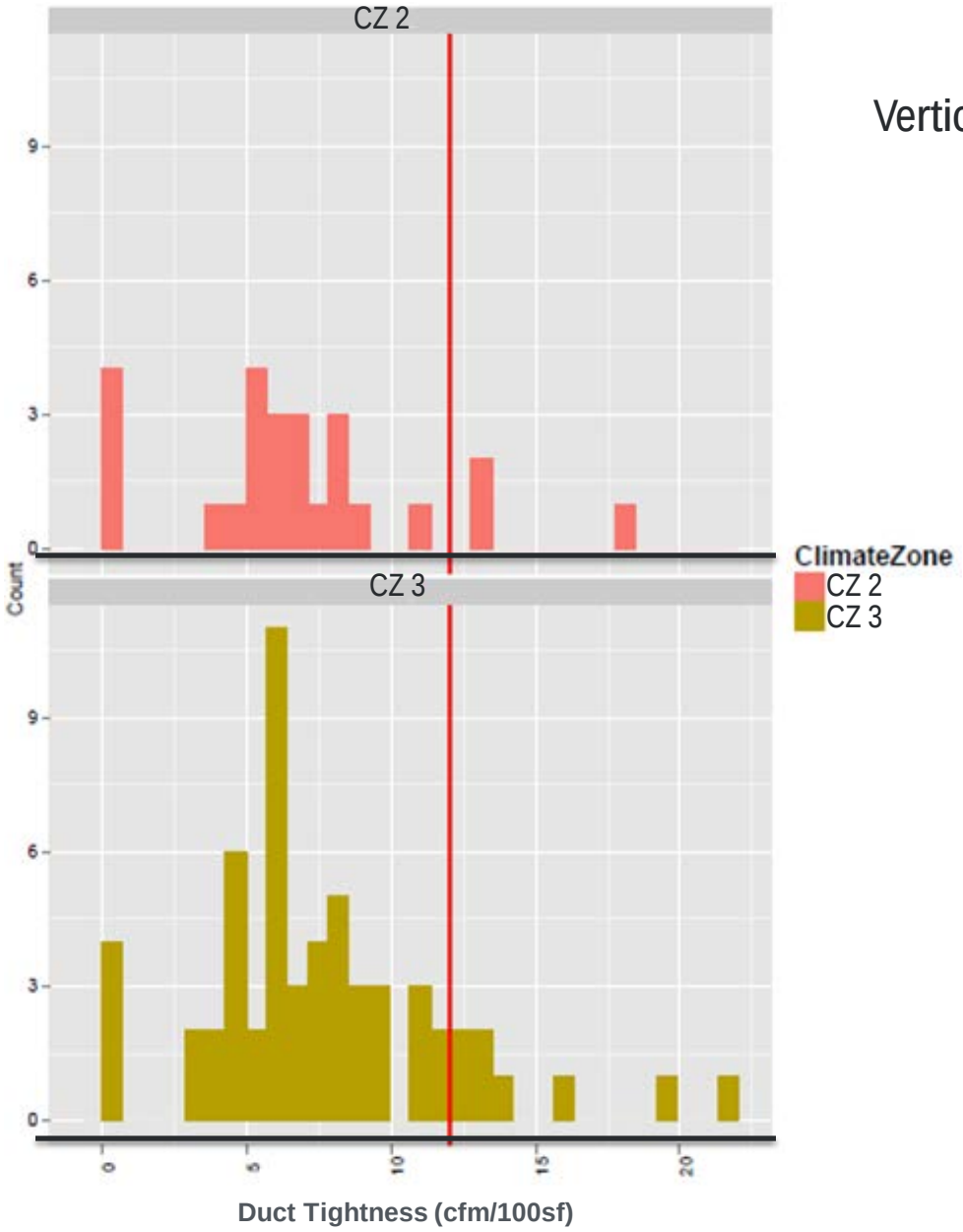
Duct Tightness – Alabama



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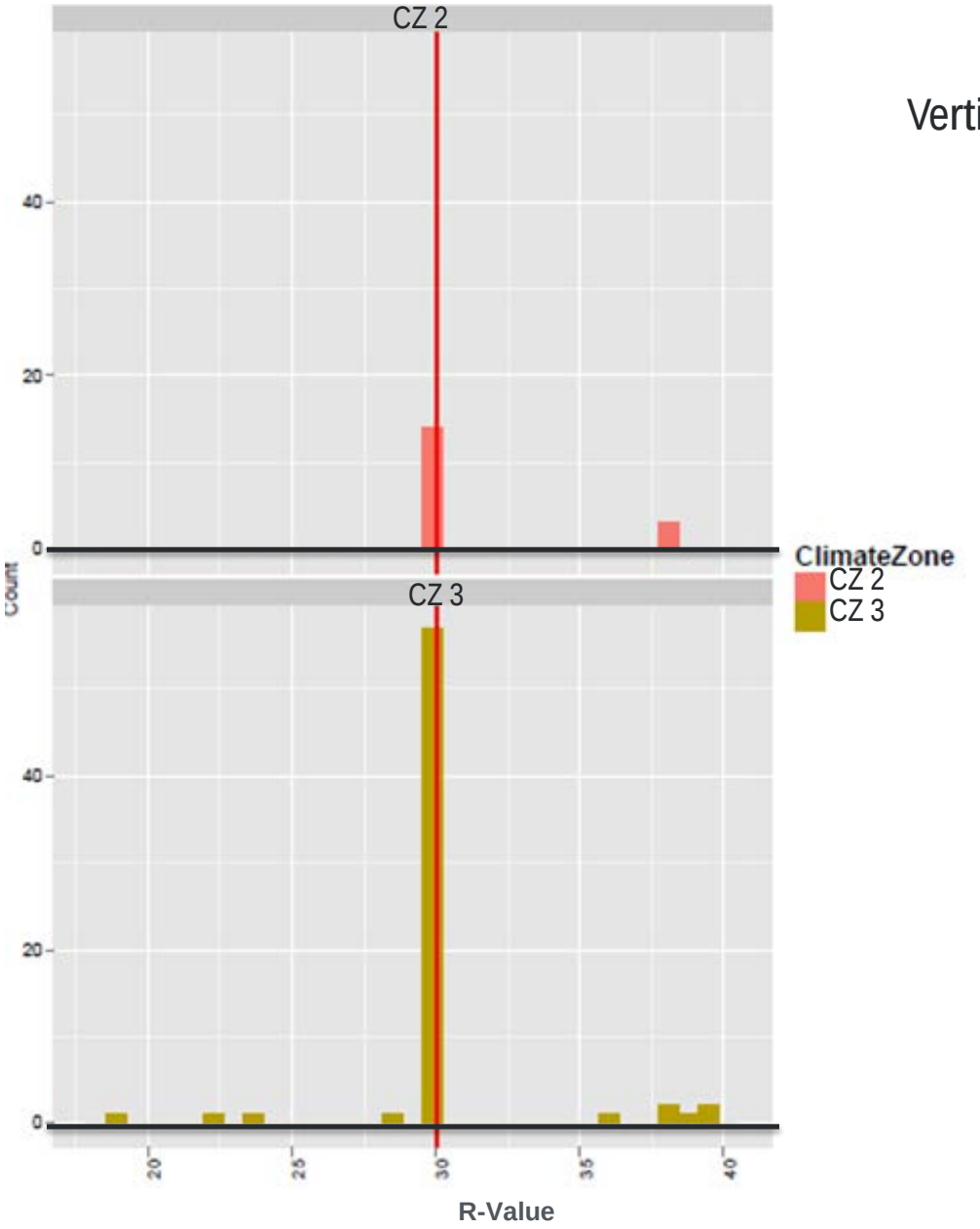
Ceiling R-Value – Alabama



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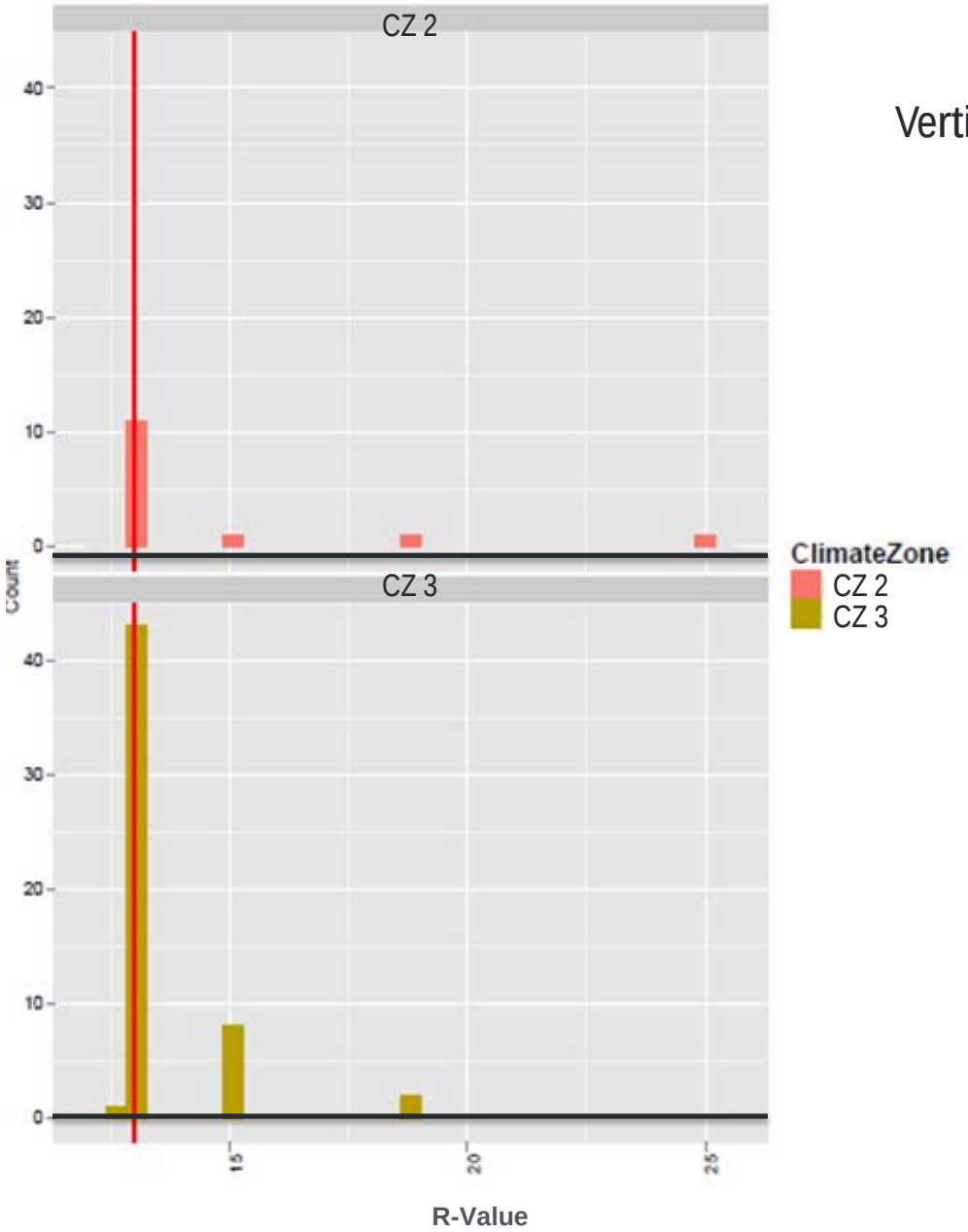
Frame Wall (Cavity) – Alabama



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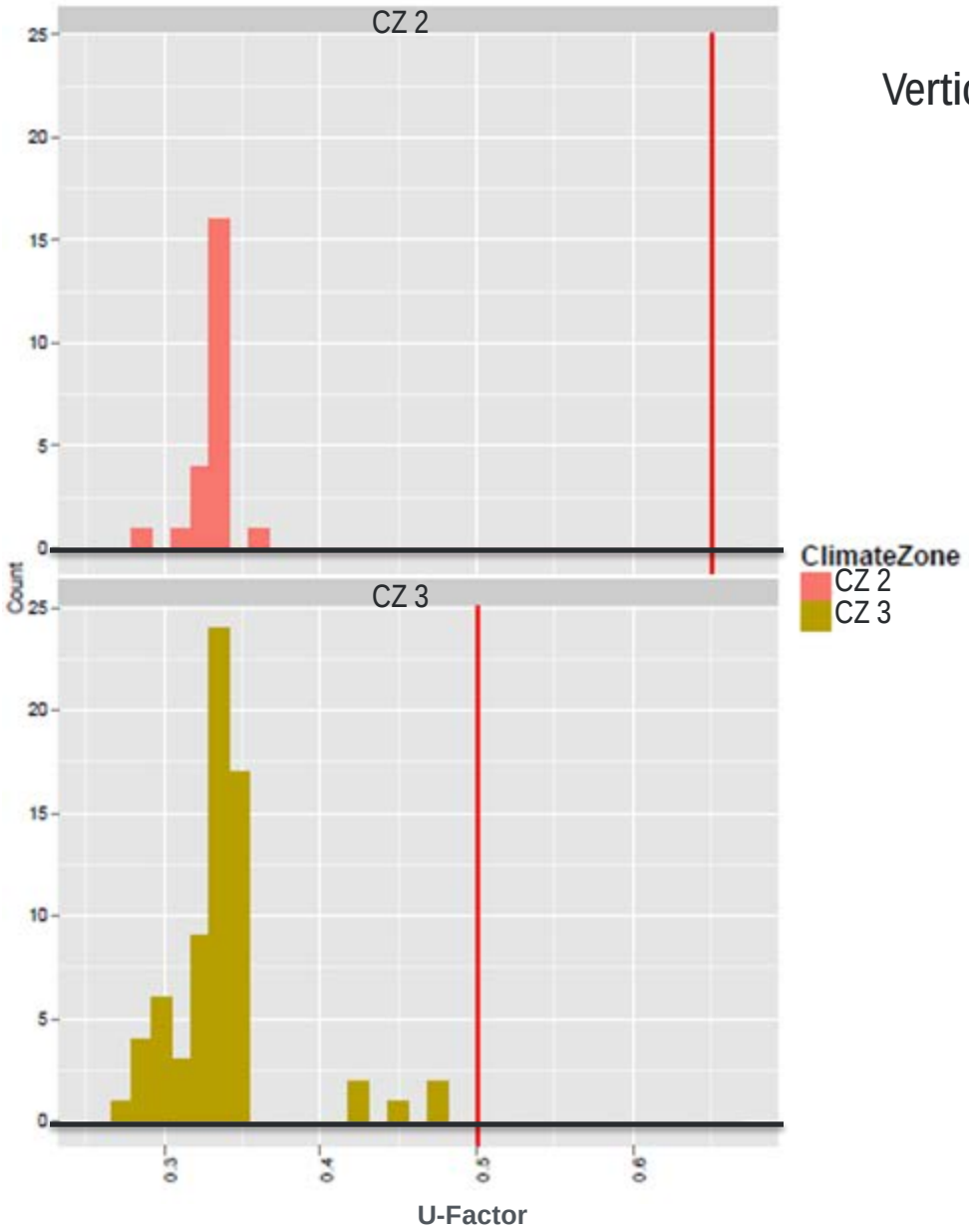
n = 68

Window U-Factor – Alabama



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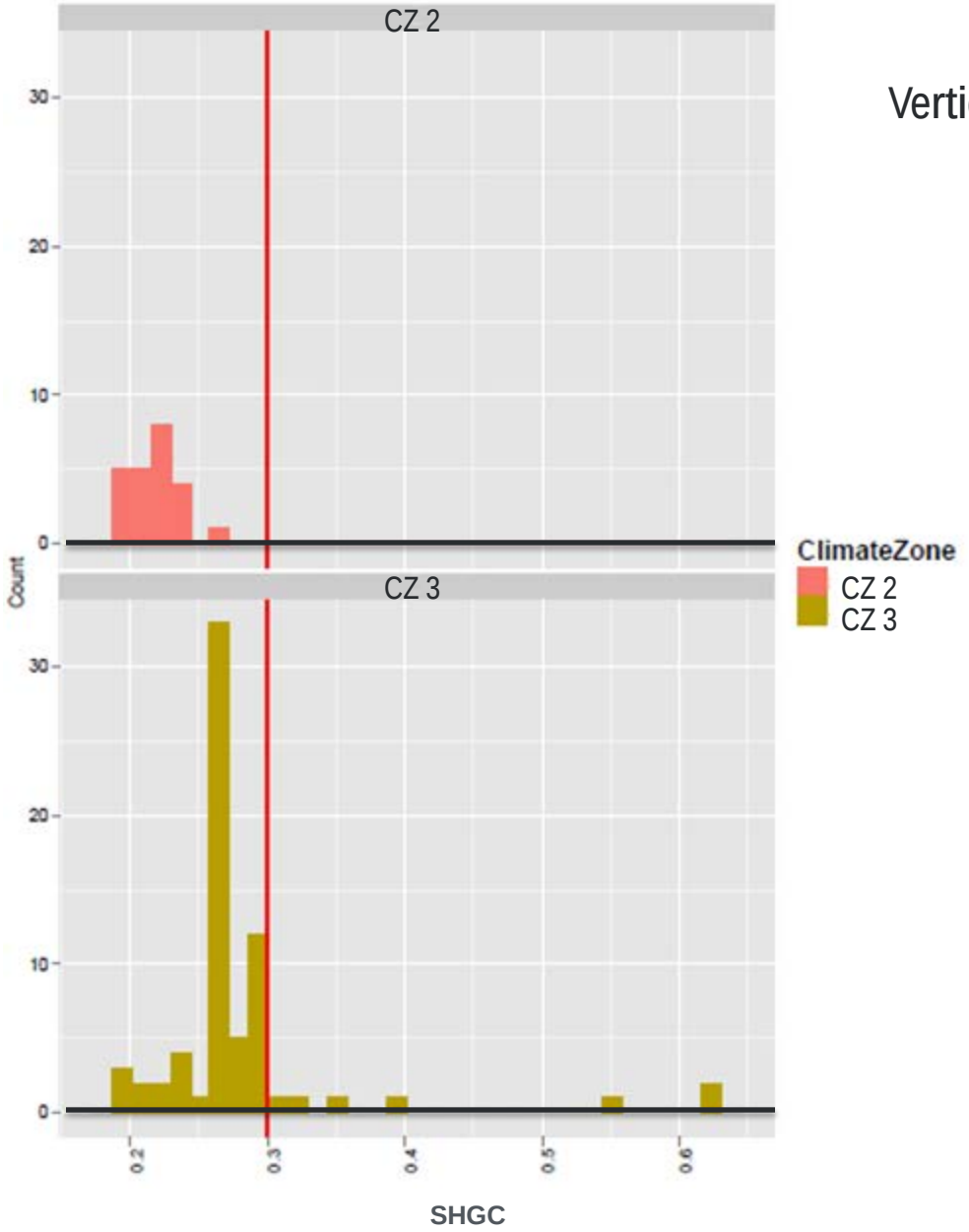
n = 92

Window SHGC – Alabama



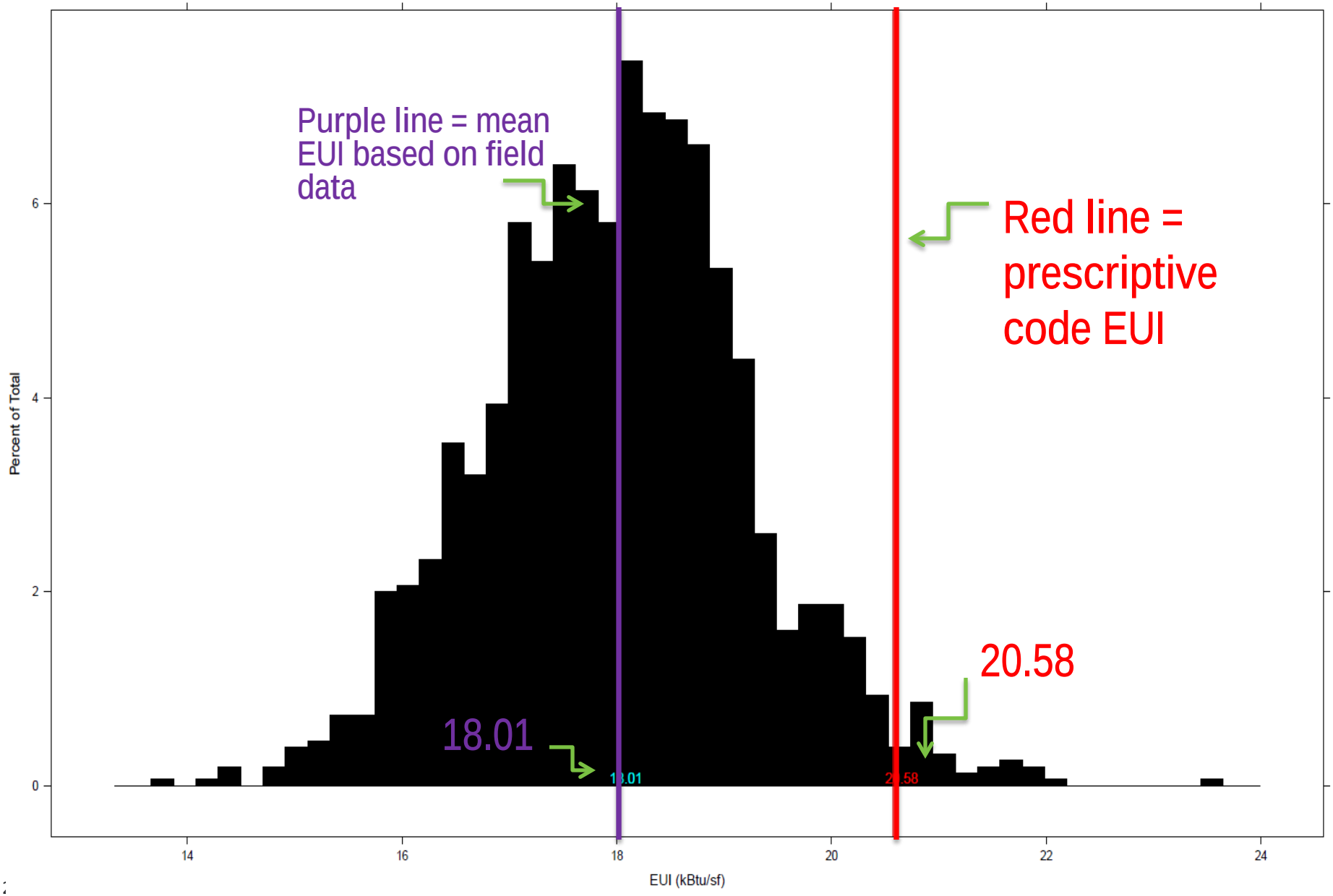
Vertical line = 2009 IECC Requirement

n = 92

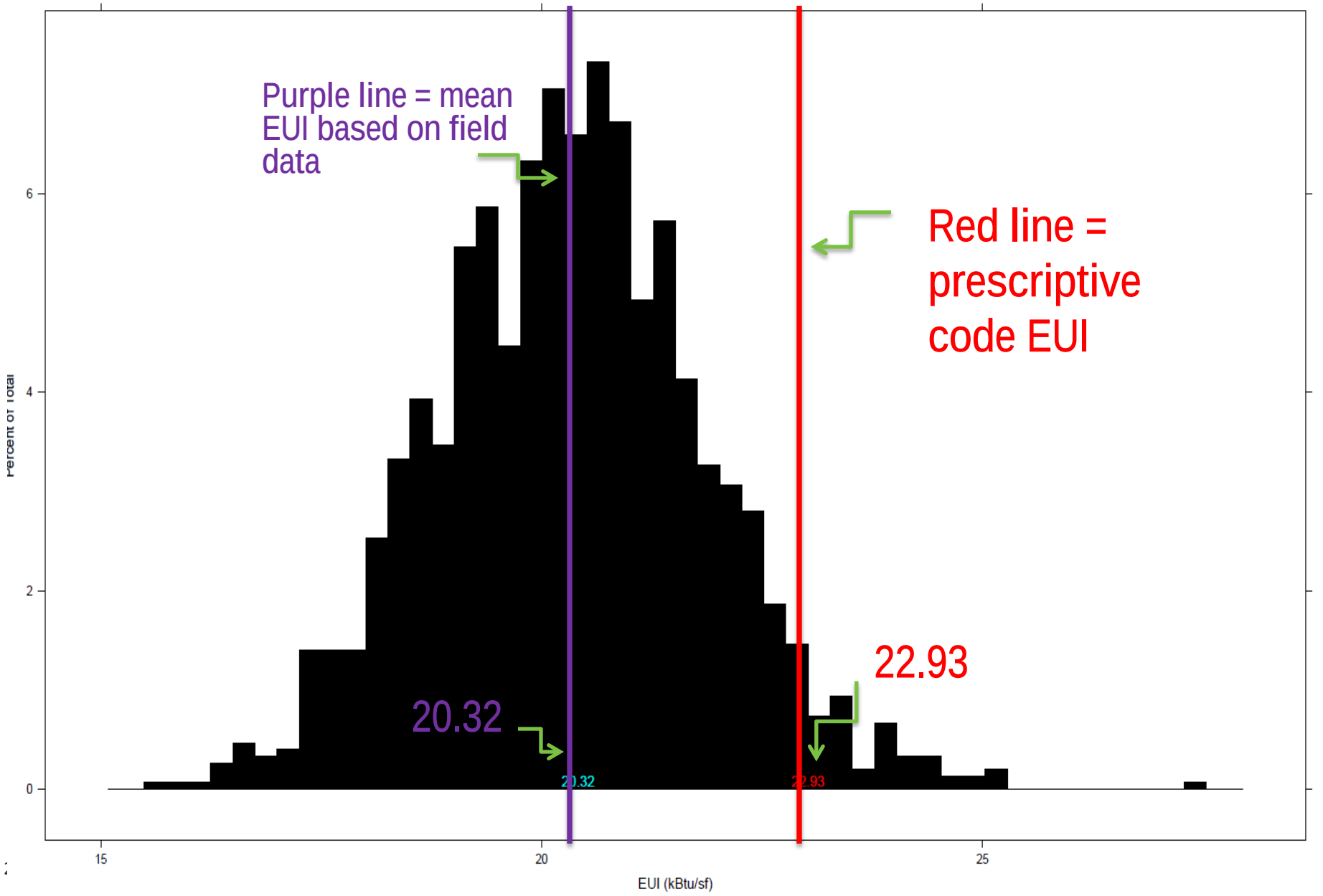
Overview of the EUI Analysis

- **Model Development**
  - Single site-visit design results in incomplete sets of key item observations for a given home
  - *EnergyPlus* requires a complete set of key item observations to create a building energy model
  - Monte Carlo process used to bridge the gap by randomly sampling the observed data to create 1500 complete sets of all key items
  - Each set used to build an energy model using DOE's single-family residential building prototype making it easier to isolate influence of the code
- **Simulation Results**
  - Energy Use Intensity (EUI) only represents "code-regulated" loads
  - EUI results **not** based on actual energy use of occupied homes
  - EUI results are compared to code prescriptive minimum for each climate zone

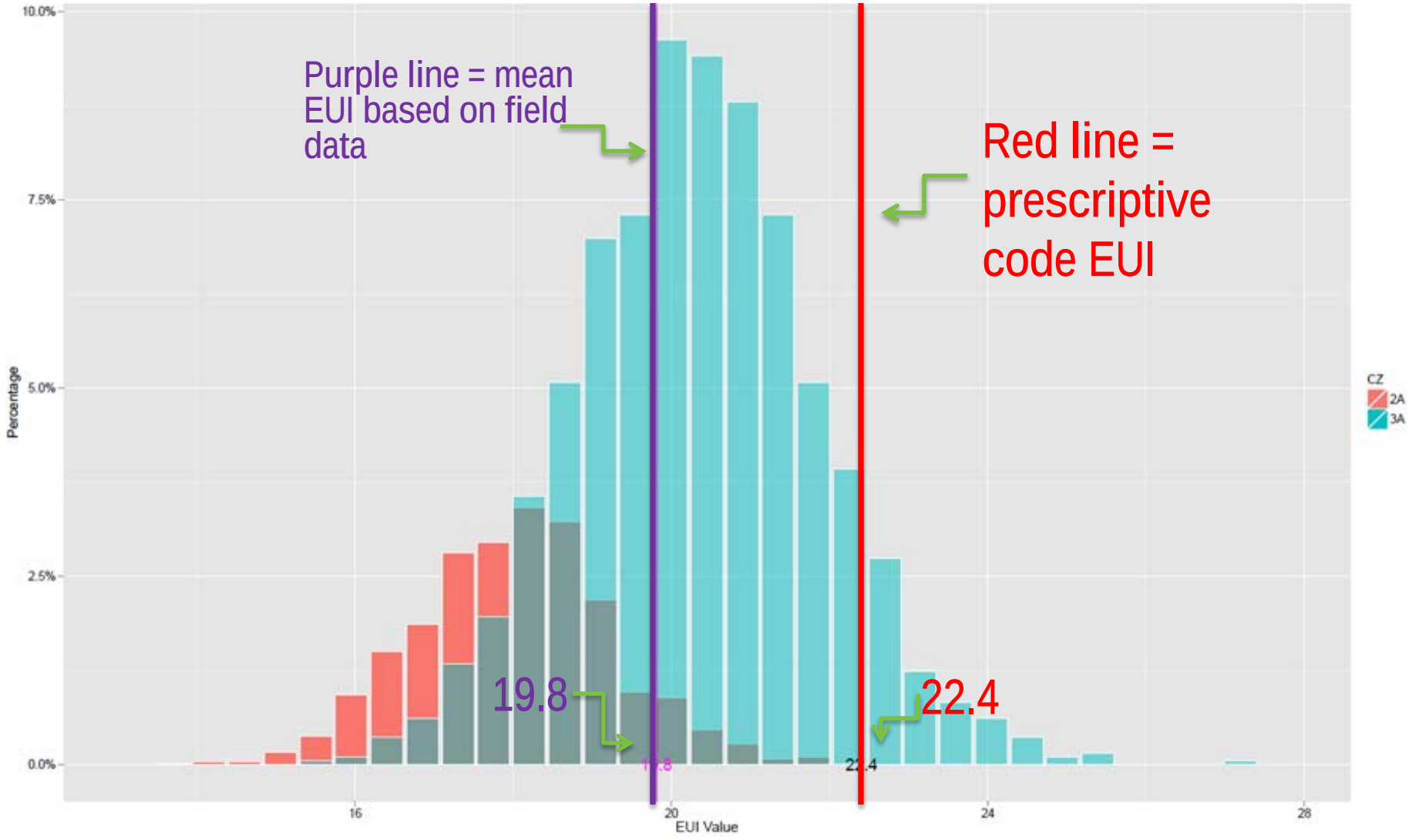
EUI – Climate Zone 2A – Alabama



EUI – Climate Zone 3A – Alabama



EUI – Statewide – Alabama



Key Drivers – Savings Potential

- Distribution of observed key items
  - Used to create energy models to generate a distribution of EUIs for the state
  - Used to identify areas with savings potential
- Applicable code requirements
  - Influence observations for some key items
  - Define the “baseline” against which observed model EUIs are compared in order to calculate savings potential
- Distribution of savings by fuel type
  - Only influences energy cost savings and emission reduction potential

Estimating the Savings Potential

- Overall Savings Potential
  - Isolate models that have a total EUI greater than the prescriptive code EUI
    - Includes interactions between all measures as well as the impact of random sampling, resulting in a conservative savings estimate
- Measure-Level Savings Potential
  - Use only worse-than-code observations for a particular measure to conduct new simulations to isolate potential savings from that specific measure
    - Ignores interactions between the measure under consideration and other building components, resulting in an optimistic savings estimate
- Use the estimated average energy and cost savings along with projected annual construction to estimate overall savings potential for each state

Savings Potential

- Calculated in two ways for multiple needs
  - Whole-building level (most conservative = lower bound)
  - Measure level (upper bound)

Savings Potential

- Whole-building level, lower bound estimate for North Carolina:

Item	NC Code – 1yr
Energy Savings Potential– Million Btu/year	26,805
Total Dollars Savings Potential per year	$427,428
Emissions Reduction Potential – metric tons (CO2e per year)	1,149

Savings Potential (cont.)

- Measure level, upper bound estimate for North Carolina:

Measure (1 yr)	Total Energy Savings Potential (MMBtu)
Lighting	16,128
Envelope Tightness	14,107
Duct Leakage	18,084

RESULTS

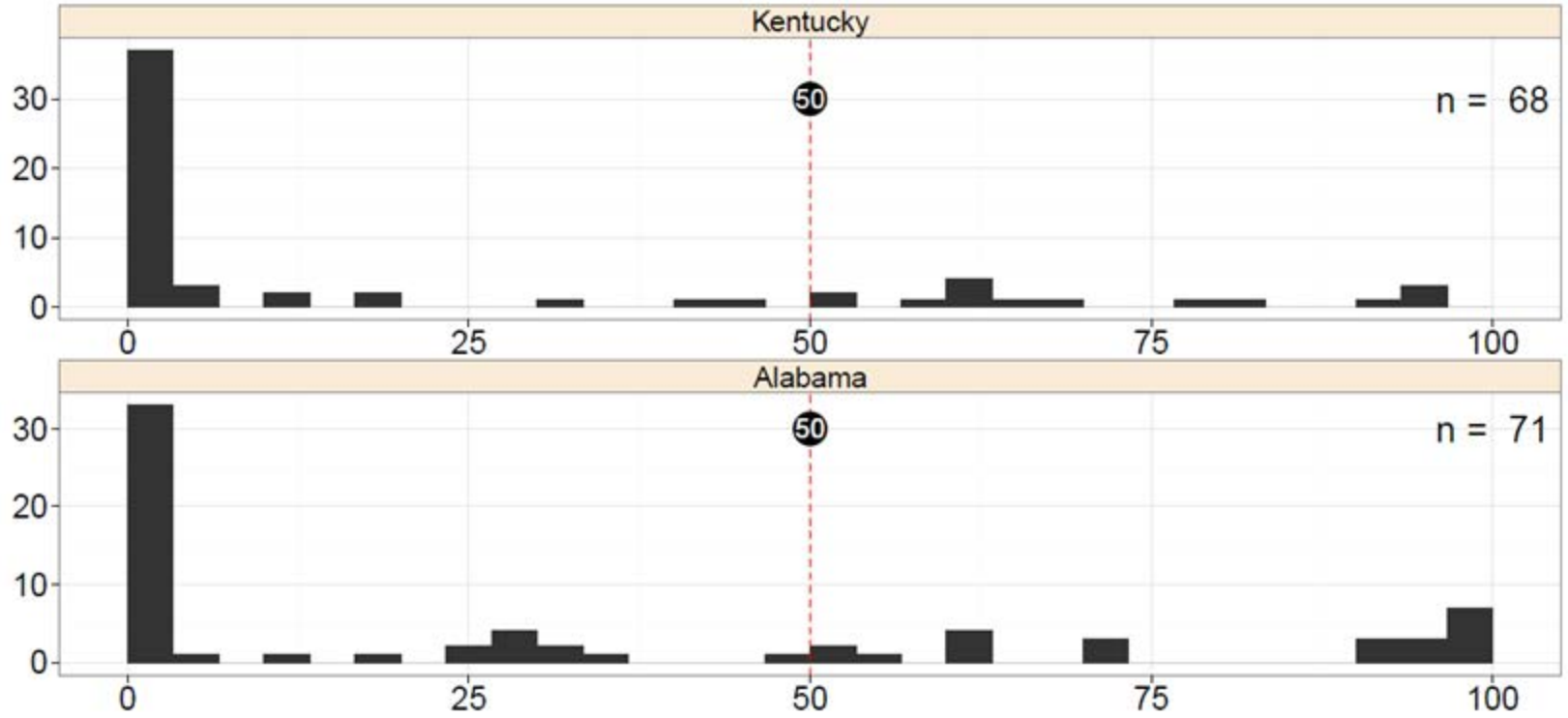
Initial Results Package

State Comparisons

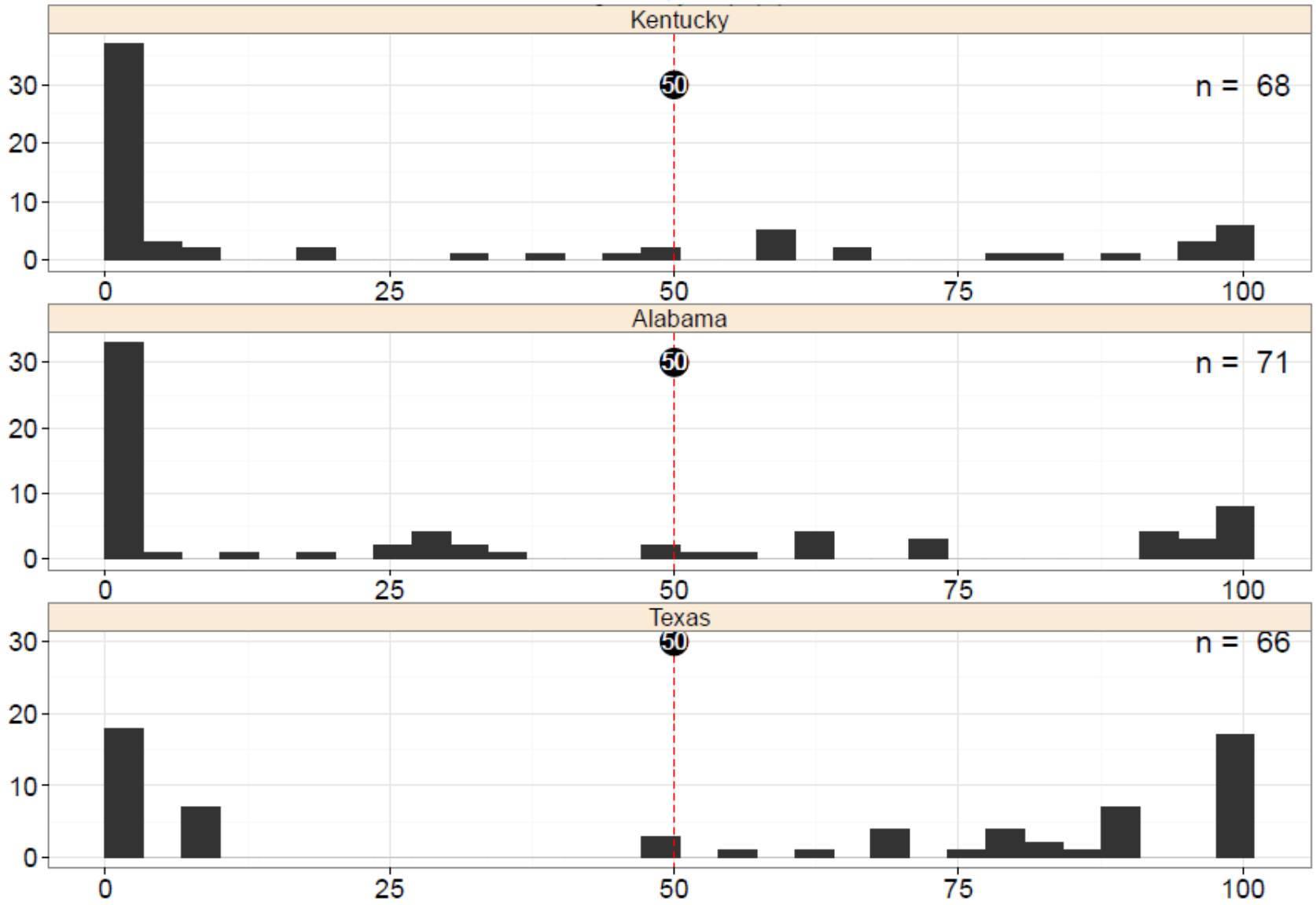
Interesting Results / State Comparisons

- Lighting
- Envelope Tightness
- Windows
- Duct Leakage
- Above-Grade Frame Walls

Lighting



Lighting



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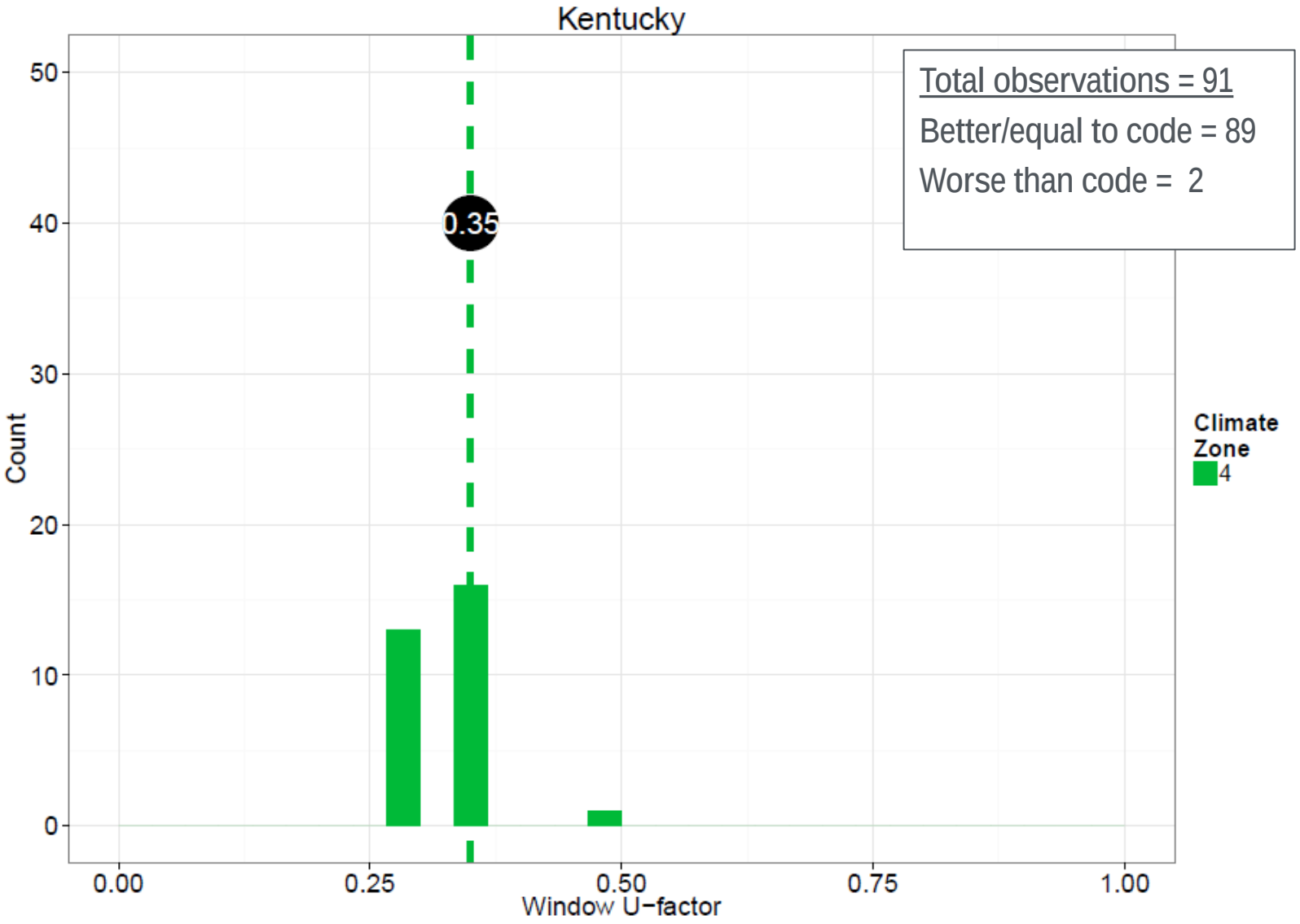

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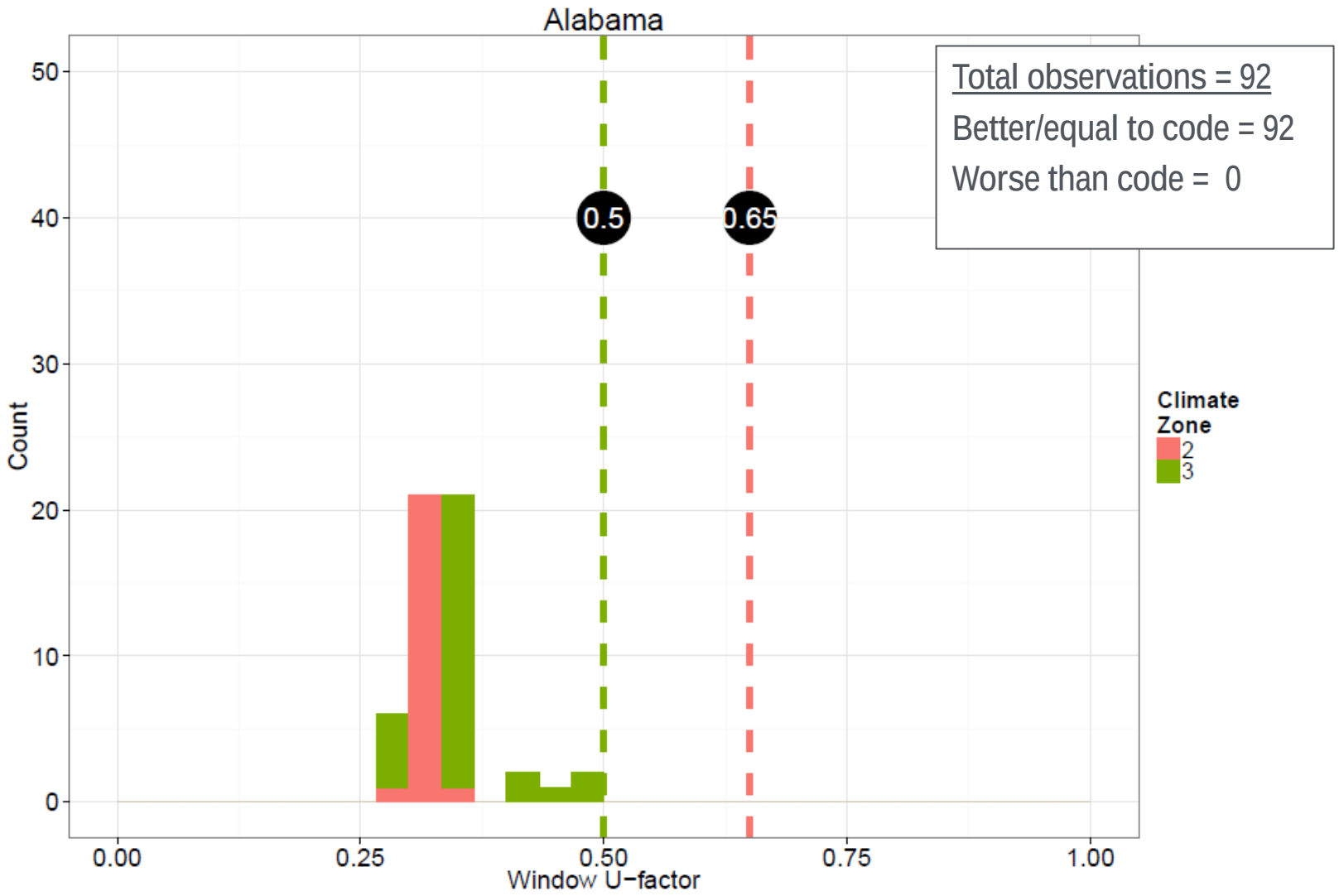

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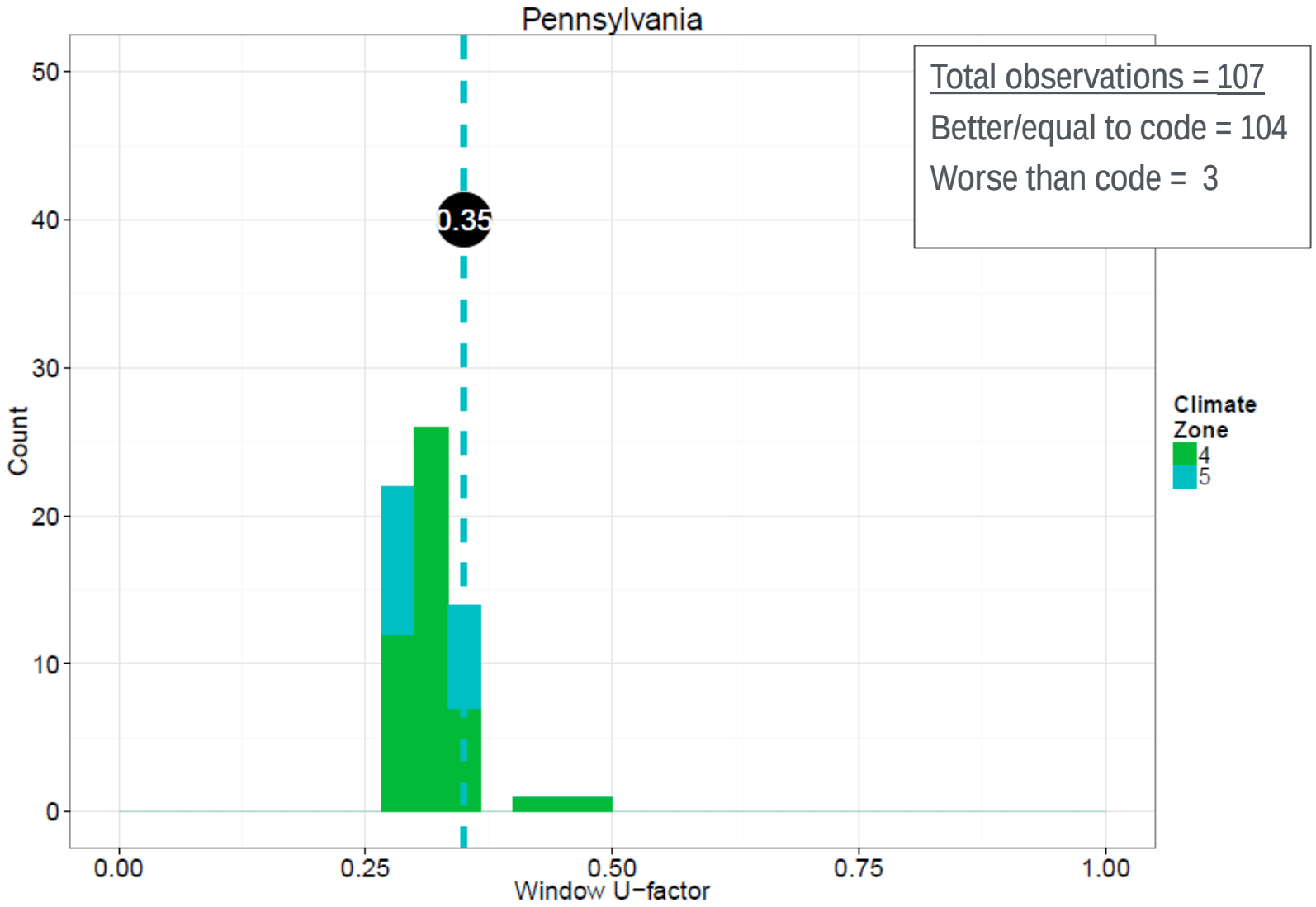

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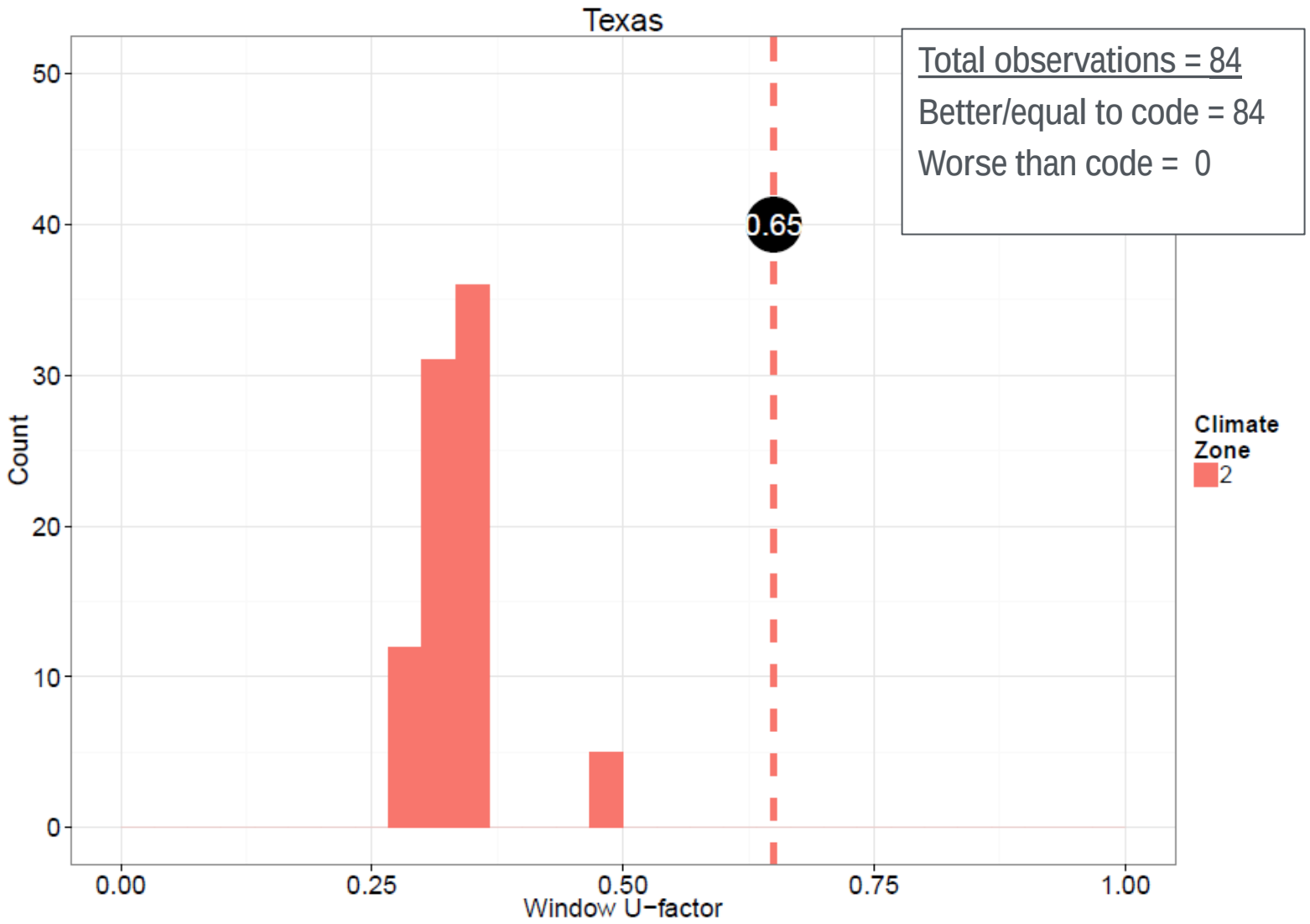

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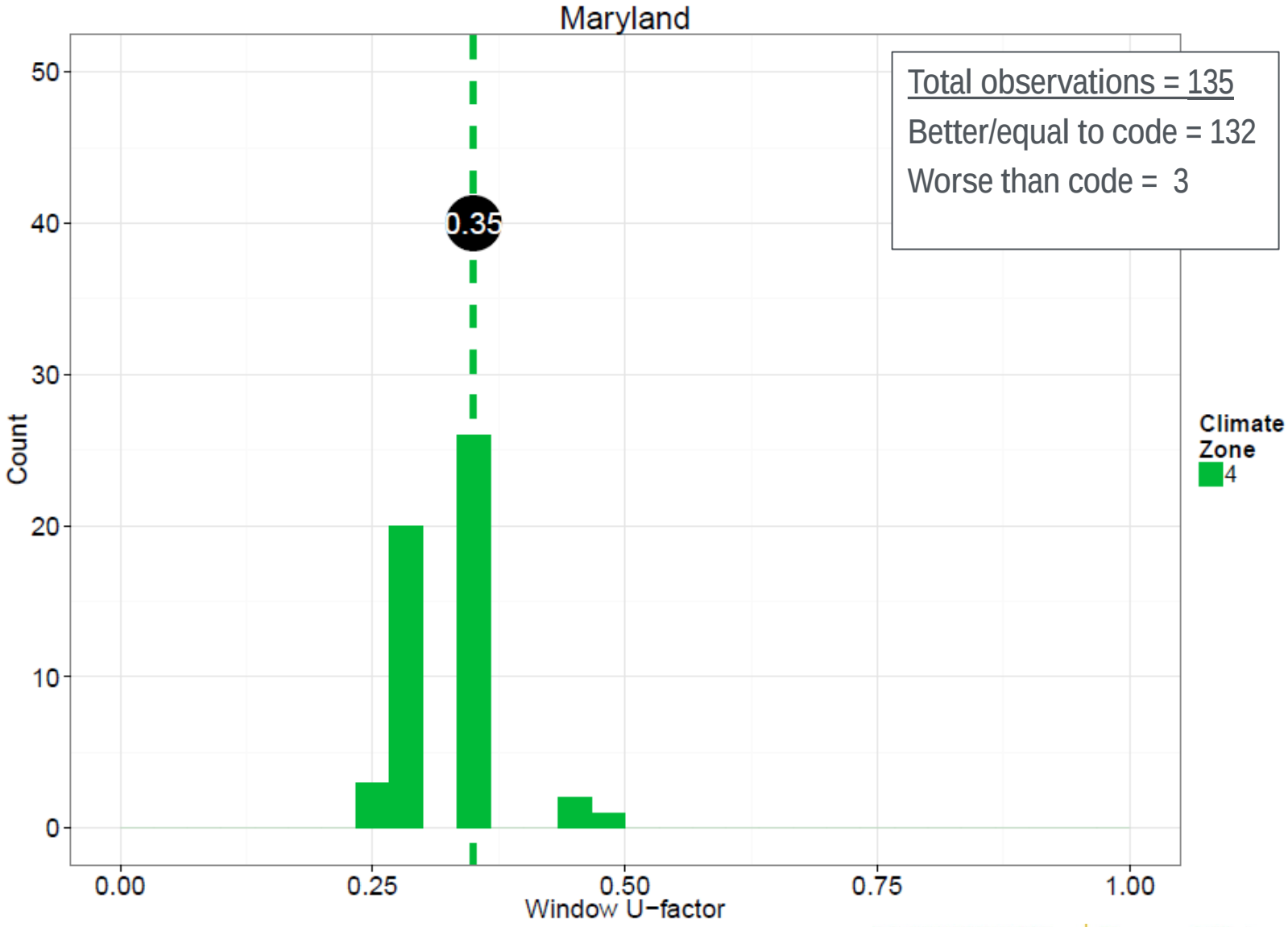

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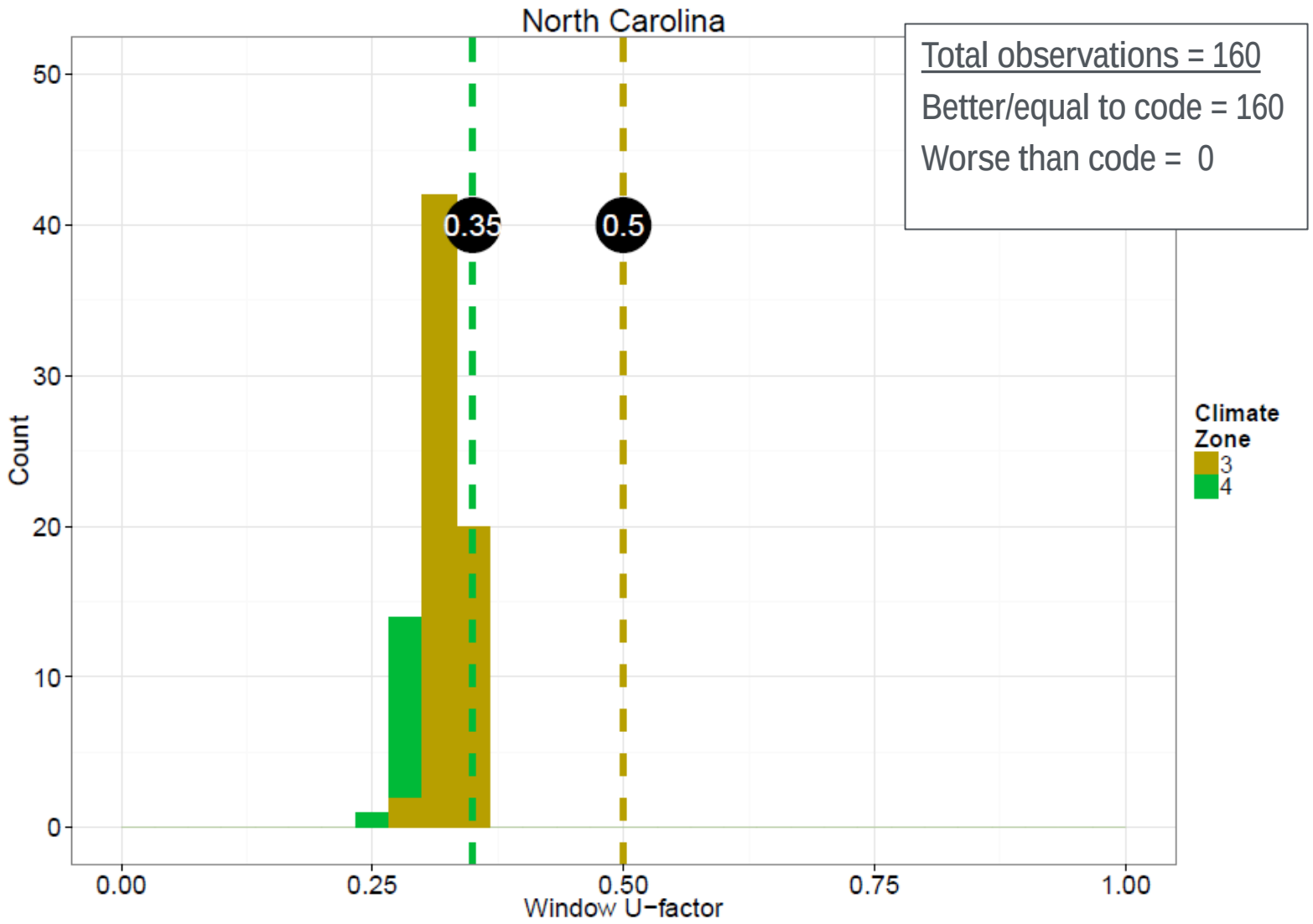

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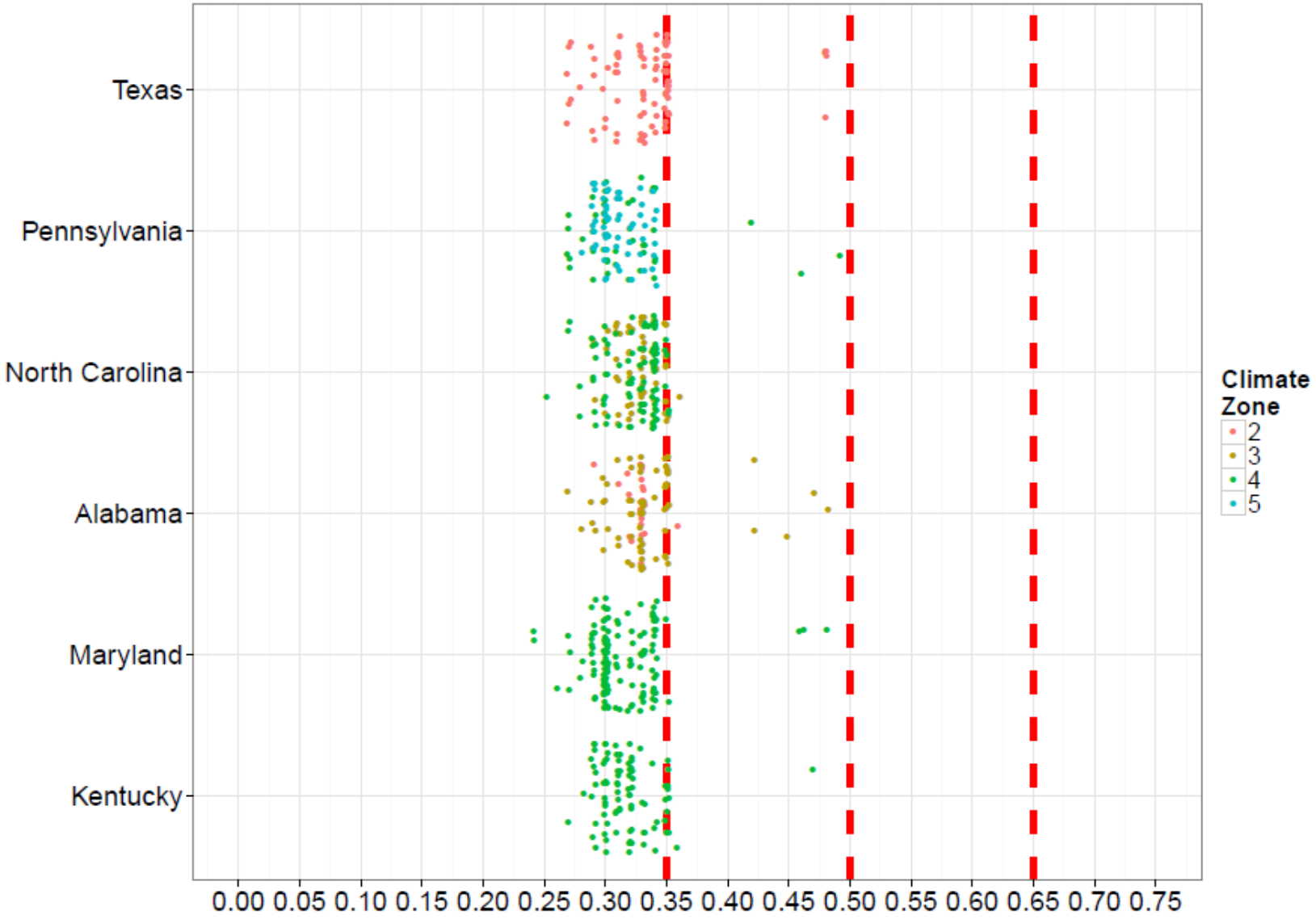
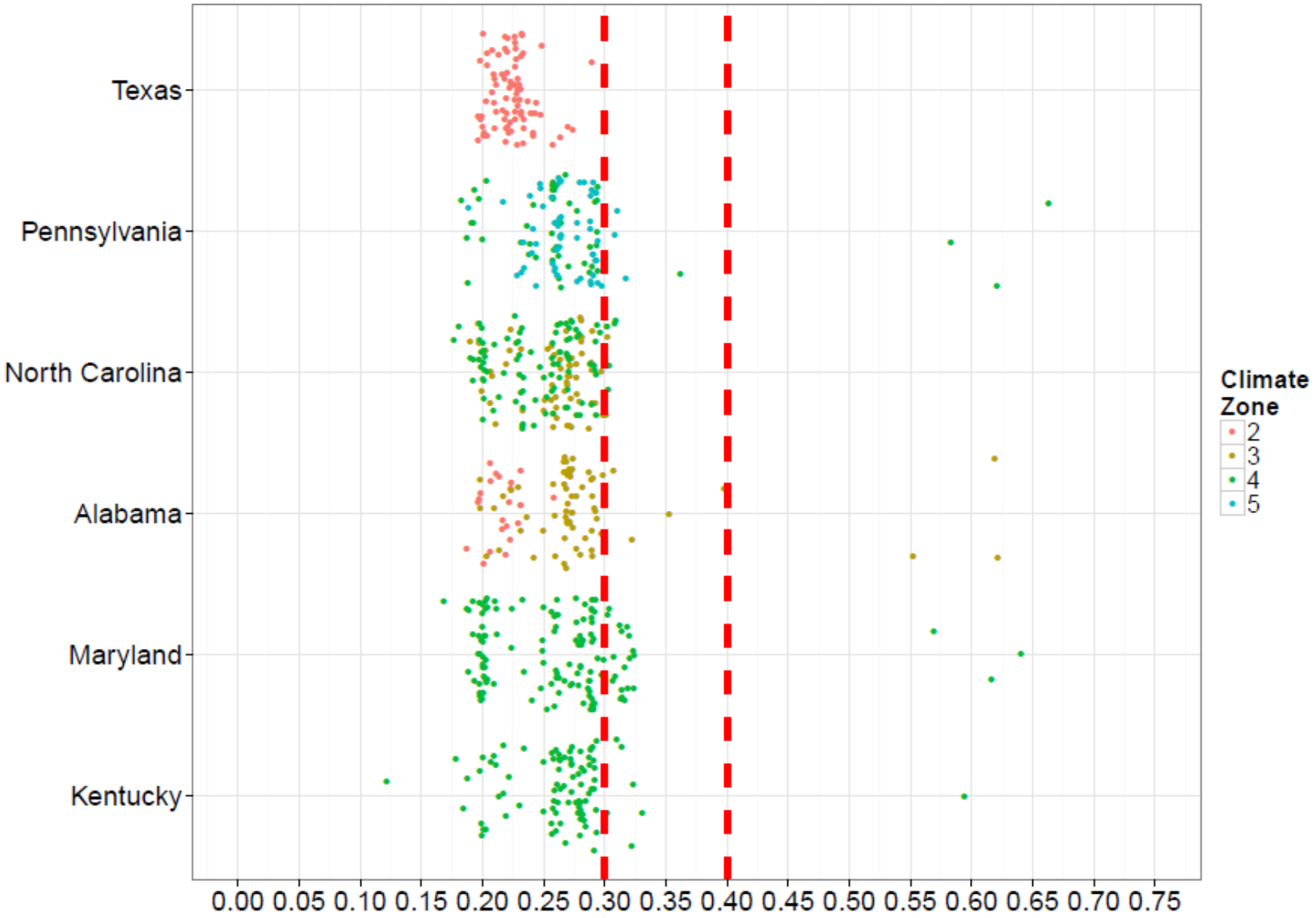
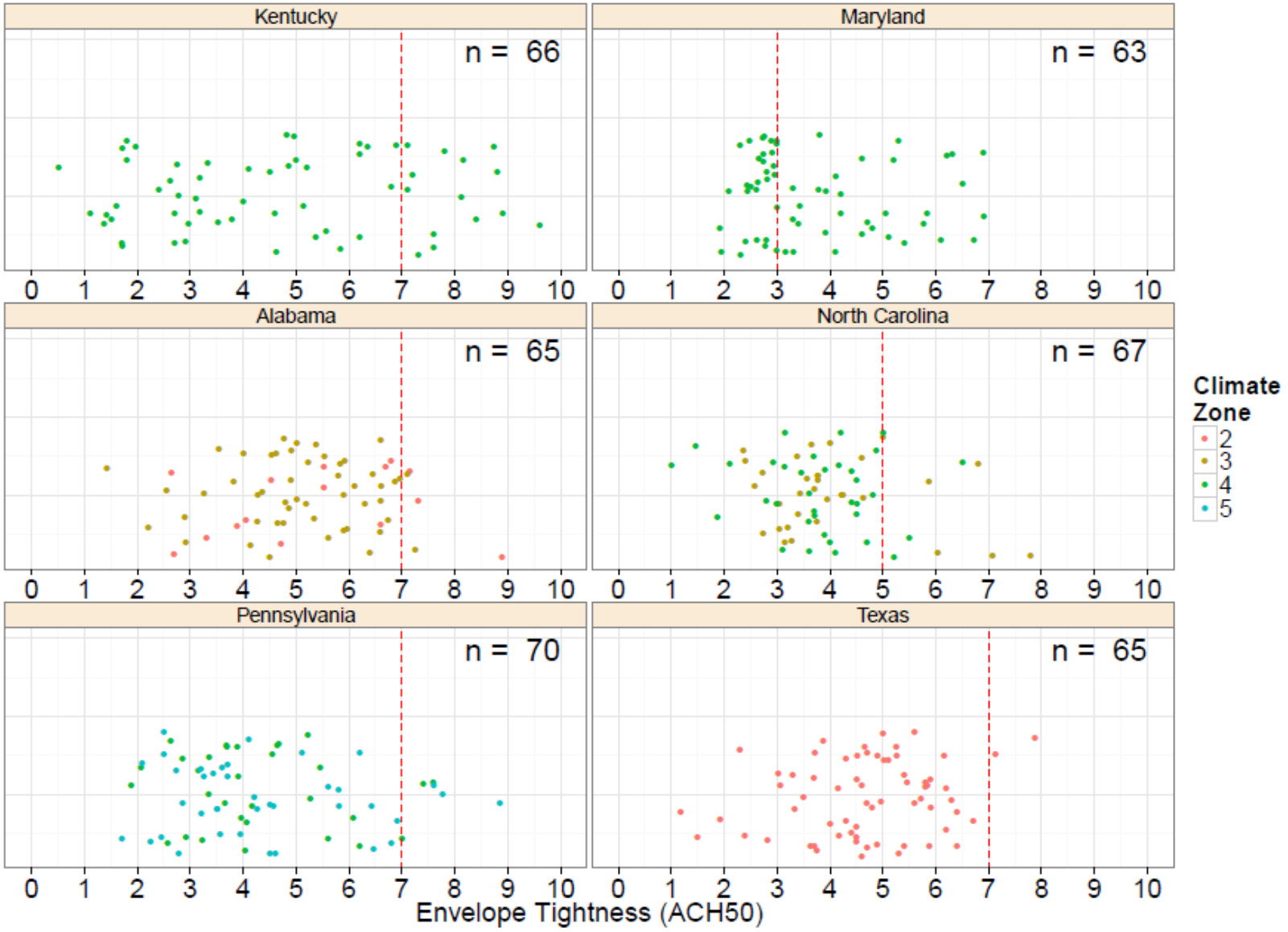


Window SHGC



Envelope Tightness



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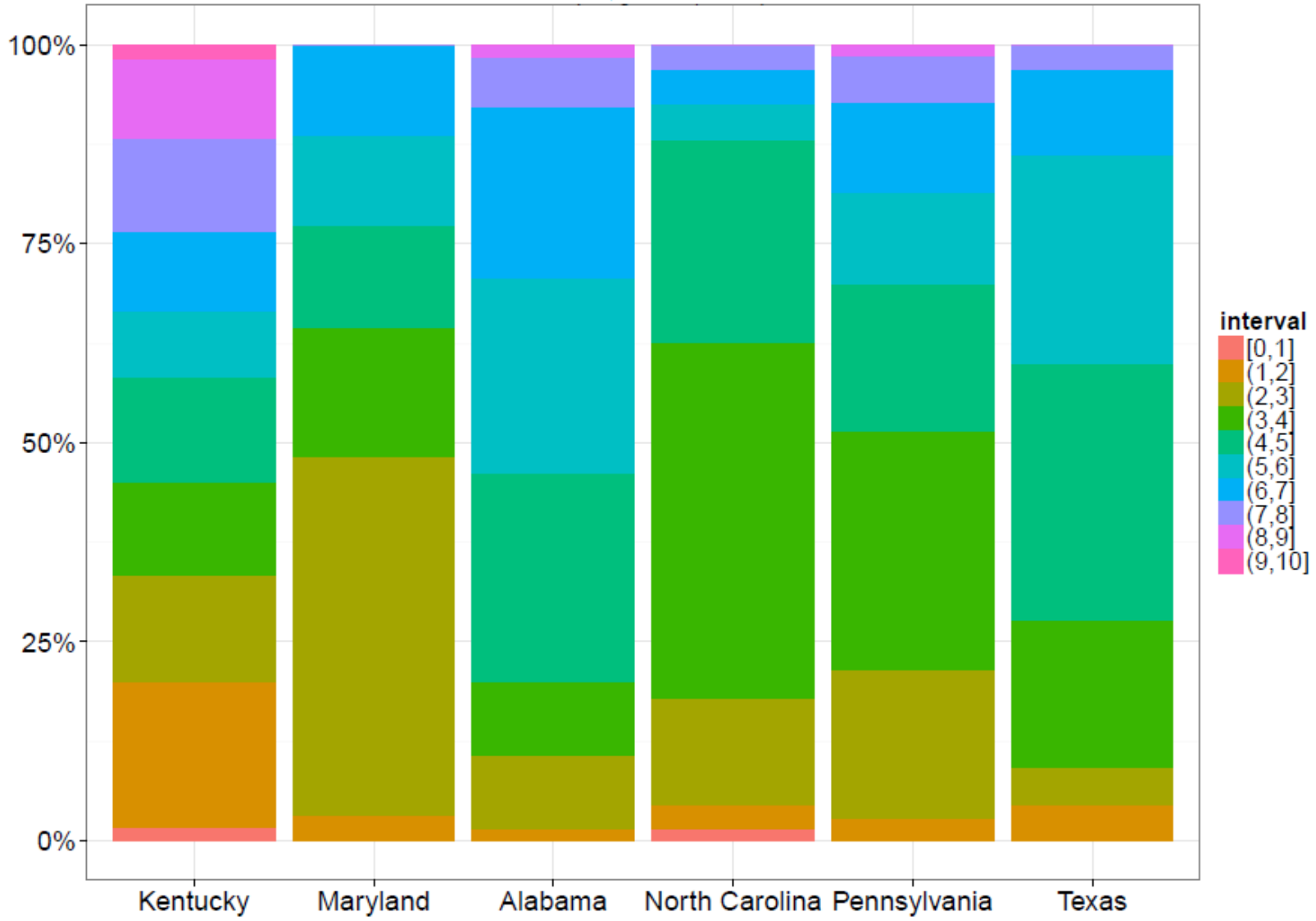

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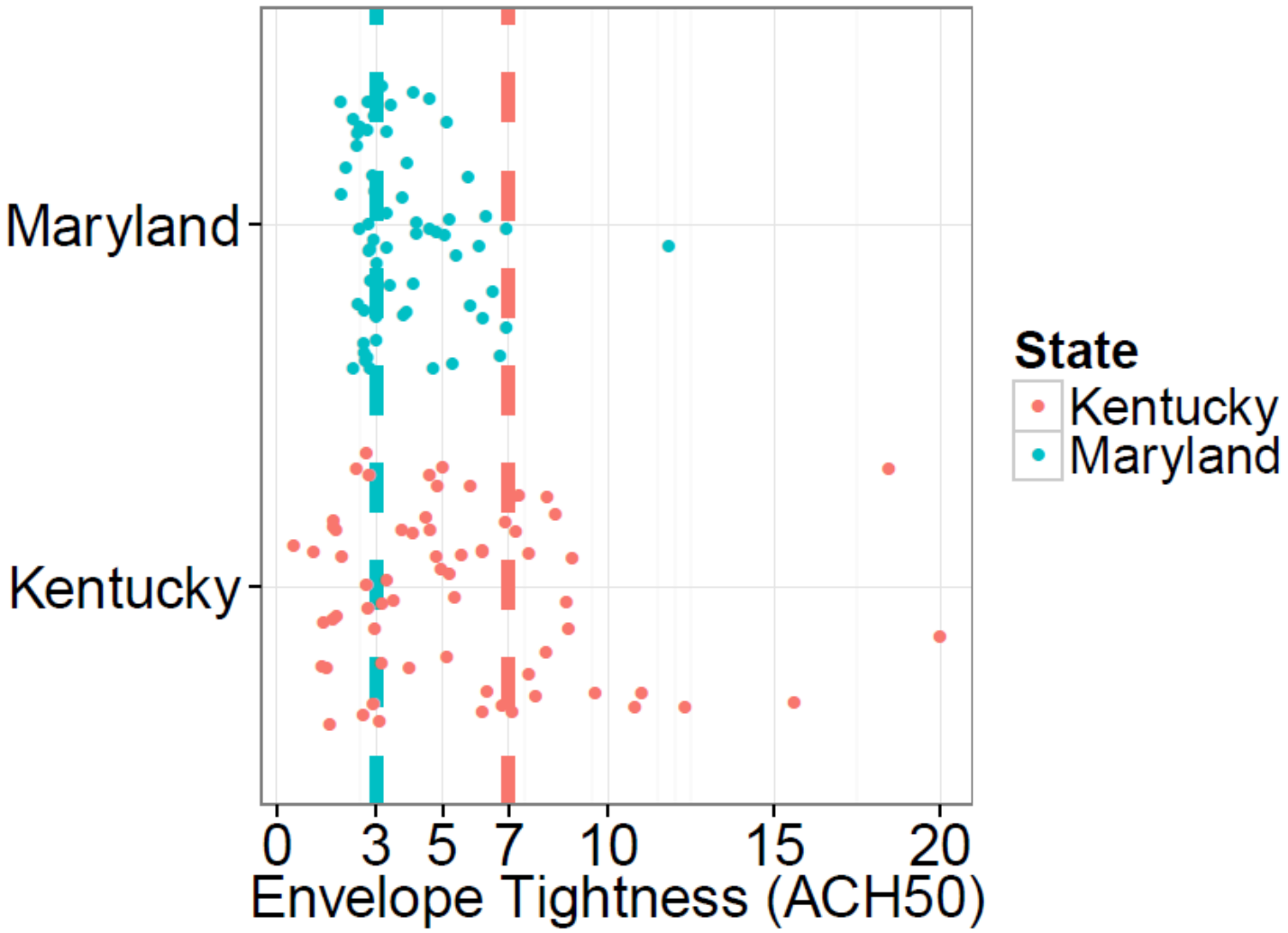

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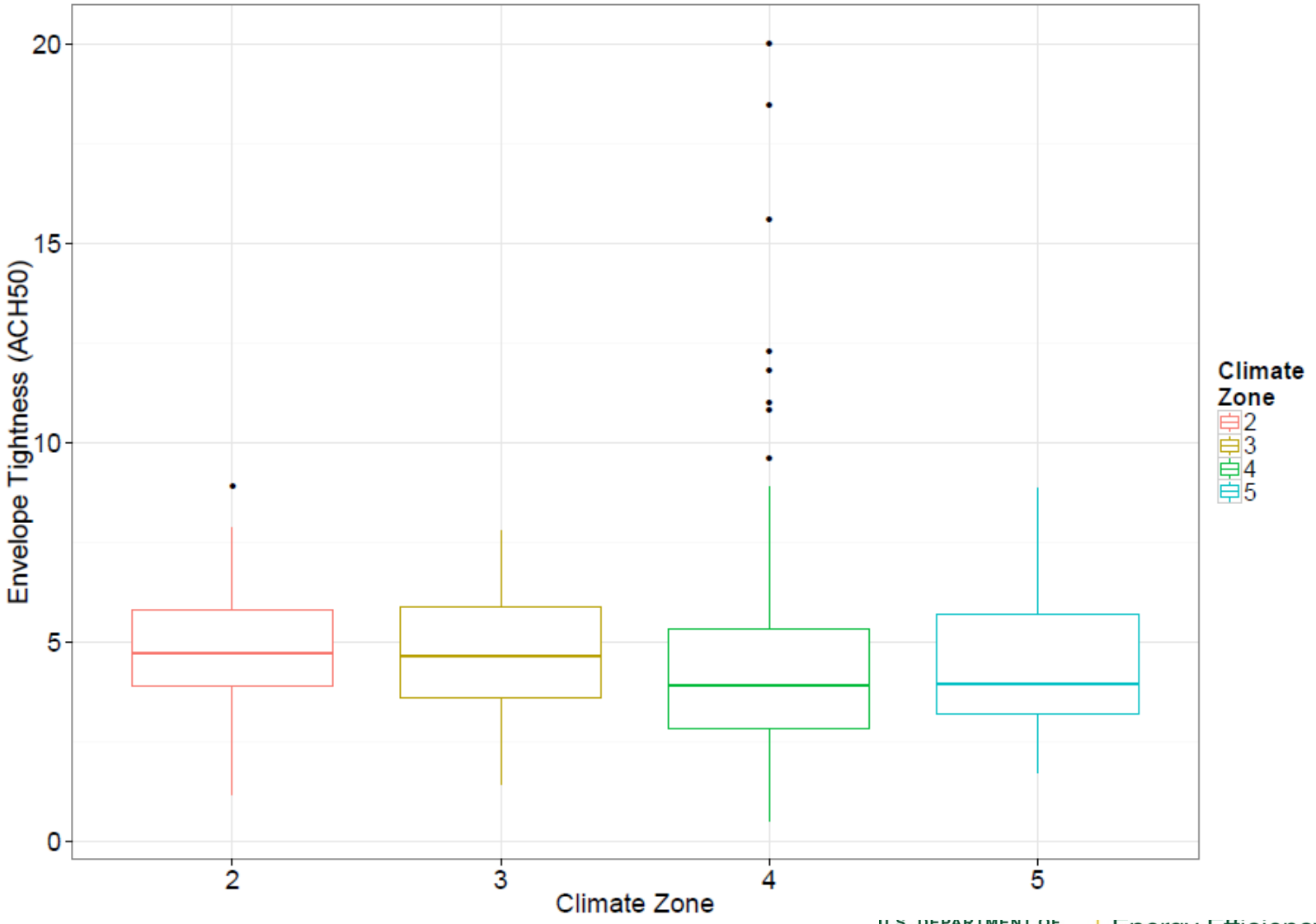
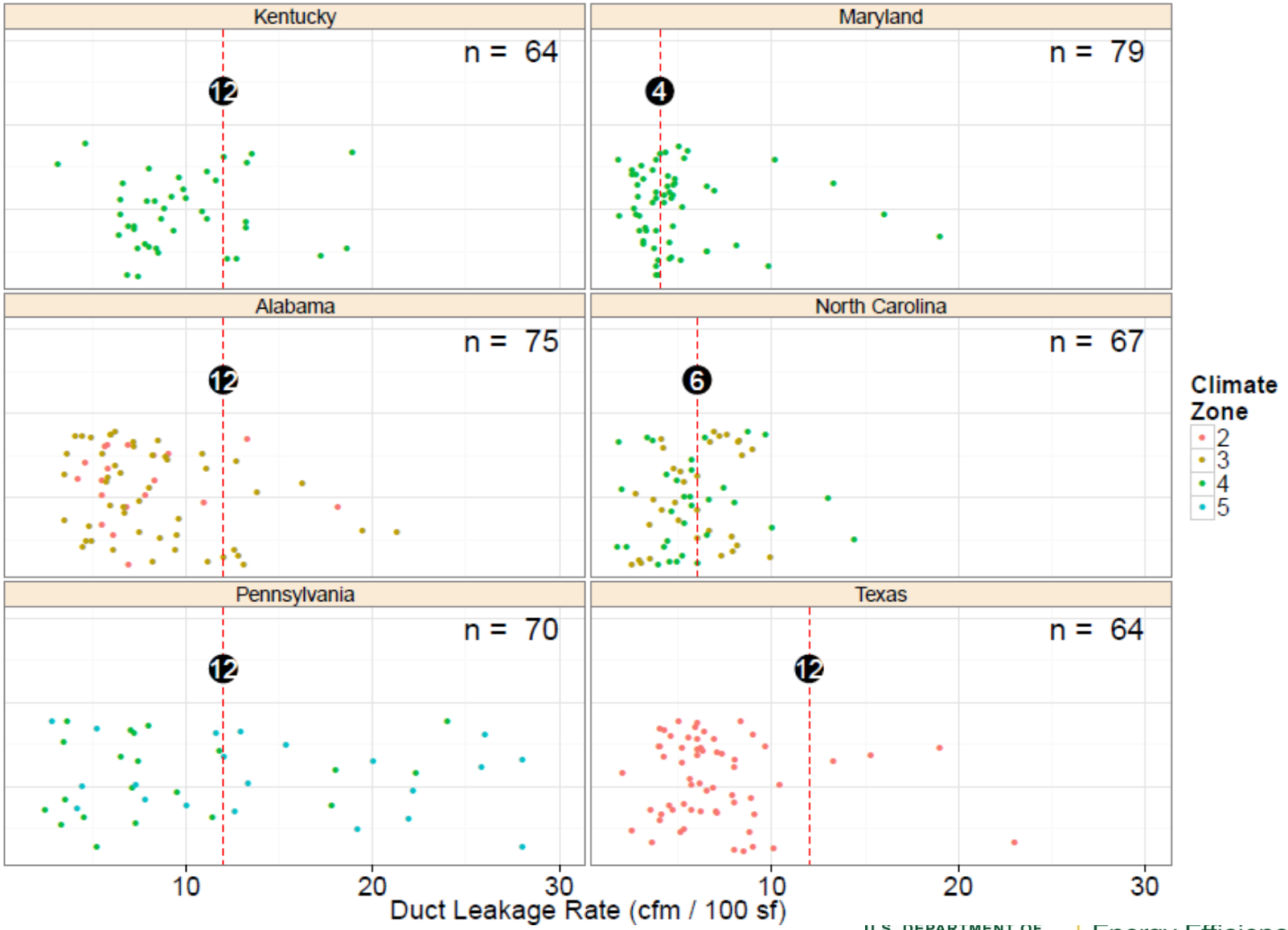
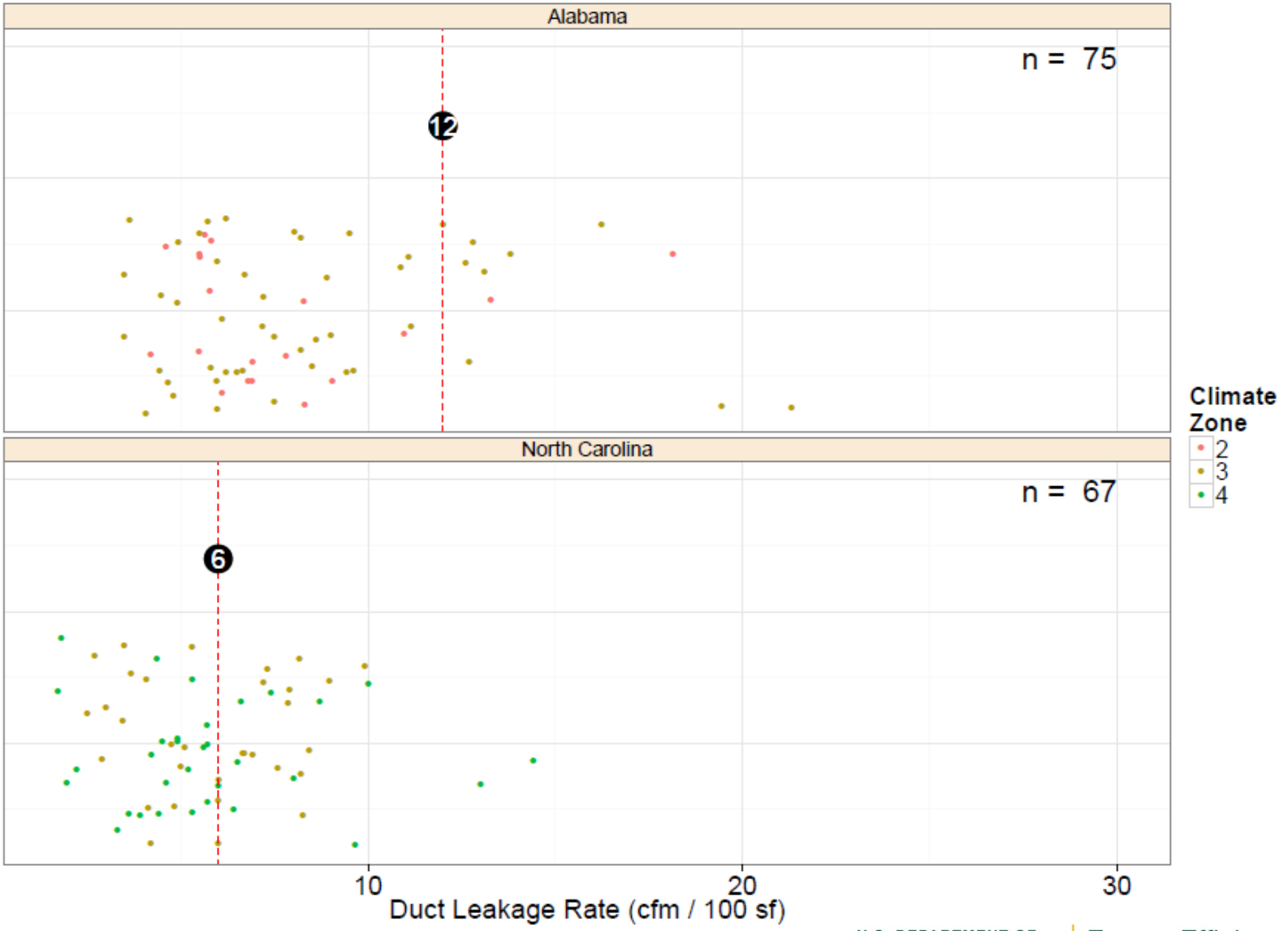


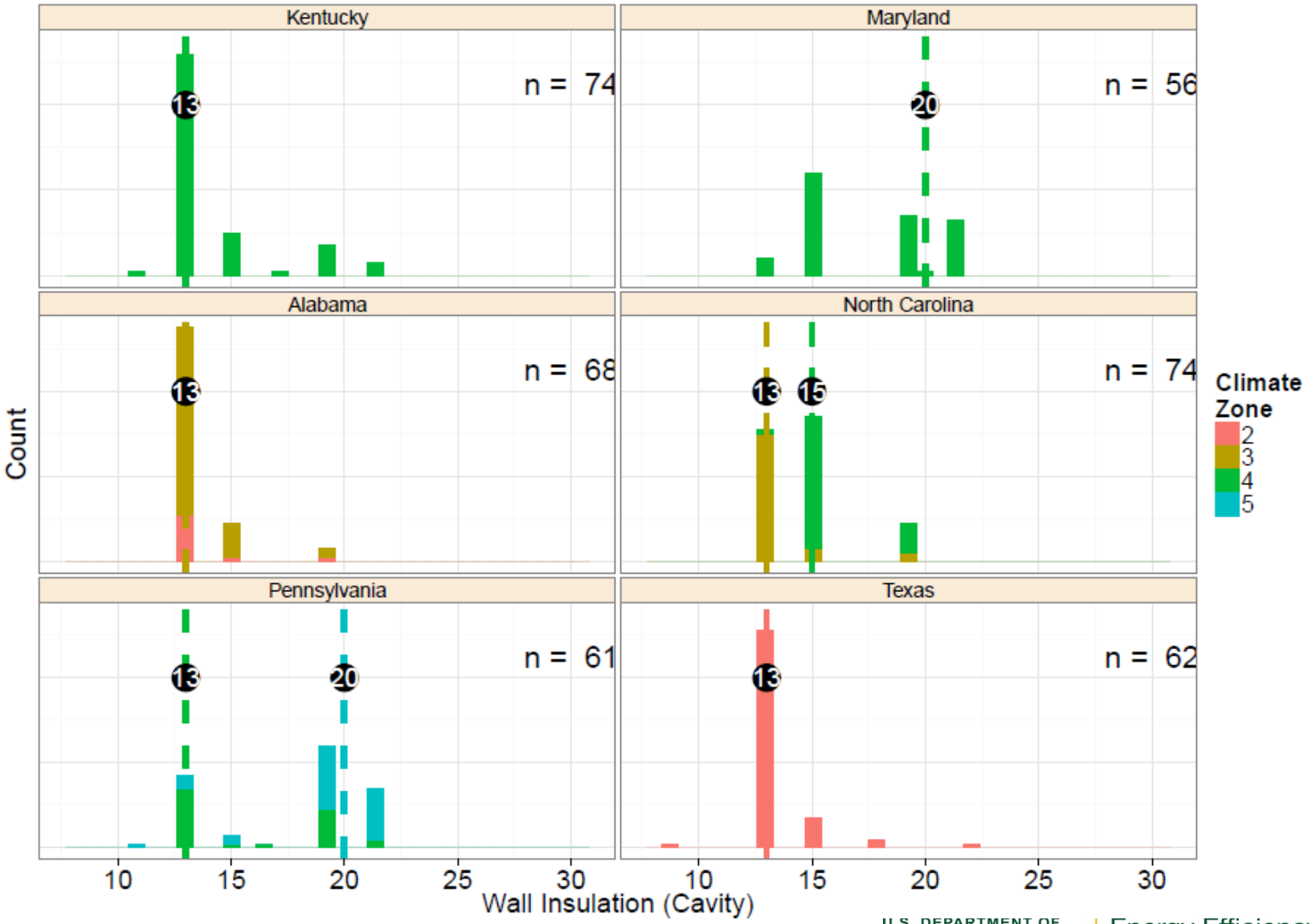
Duct Leakage



Duct Leakage



Above-Grade Frame Walls (Cavity)



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Preliminary Conclusions

- Builders and building officials are doing a very good job meeting adopted codes.
- On average, homes are using less energy than would be expected based solely on the prescriptive code in 5 of 6 six states analyzed.
- There is still significant savings potential from individual code requirements that do not comply.
- Individual Requirements
  - Some are consistently better than code (e.g., windows)
  - Some are inconsistent with code (e.g. lighting)
  - Some are virtually always exactly at code (e.g. walls)
  - Nothing is consistently worse than code
- Similar studies underway in MI, AR, GA, WV. More data to come!
- Field studies are critical to understanding the patterns of compliance and their impact on energy.

Planning a Study?

- Budgeted cost was $115,000 per baseline study. Budget adequate in almost all states.
- PNNL services available free to those following methodology:
  - Sample design
  - Customized data collection forms
  - Analysis
- Commercial methodology not yet available but is in development. Target date is late 2017.

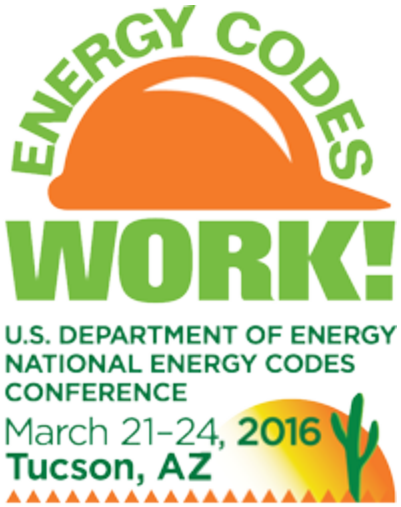
Available Resources

- Spreadsheets containing all field data *(available now)*
- Webinar presentation slides *(available now)*
- Methodology guideline *(coming soon)*
- Methodology technical support document *(coming soon)*
- State reports *(coming soon)*
- Overall project report *(available at the end of Phase III)*

All resources available from:
https://www.energycodes.gov/residential-energy-code-field-study

Residential Field Code Study Contacts

- Jeremy Williams, DOE, Jeremy.Williams@ee.doe.gov
- Rosemarie Bartlett, PNNL, rosemarie.bartlett@pnnl.gov



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