FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Leveling the Playing Field on Rating Large and Small Homes: The Index Adjustment Factor (IAF)

RESNET Building Performance Conference

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A Research Institute of the University of Central Florida

Acknowledgements

- The Calculations Subcommittee of SDC 300 led the development effort for Addendum E on the Index Adjustment Factor (IAF) methodology

Calculations Subcommittee

Dave Roberts, Chair

Brian Christensen	Neil Leslie
Philip Fairey	Linda Jeng
Charlie Haack	Robert Salcido

- Linda Jeng led the due diligence effort and authored the report that verified for SDC 300 that multiple software tools respond similarly to the Addendum E specifications.

Two-Part Presentation

- Part 1: IAF for Generalists
  - What it does and does not do
  - How it works
  - Why it is needed
  - What it accomplishes
- Part 2: IAF for Geeks
  - Simulation specifications
  - Regression analysis
  - The "Drumheller Corollary"
  - Relative adjustment factors

Part 1: For Generalists

- What IAF <u>does</u> . . .
  - Provides explicit provisions and specifications to HERS Software Tool developers
  - Reduces unwarranted geometry and operating condition inequities
- What IAF <u>does not do</u> . . .
  - Increase the responsibilities of Raters and RFIs
  - Increase the cost of HERS Ratings.

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How It Works

- Addendum E-2018 created an Index Adjustment Factor (IAF)
- IAF is applied to the ERI/HERS Index as currently calculated to reduce inequities caused be floor area, number of bedrooms, and number of stories

Adjusted HER Index = (HERS Index) / IAF

Why do This?

- Anecdotal reports indicated that home geometry and operating conditions played a significant role in the ERI/HERS Index
  - As conditioned floor area increases, the Index goes down
  - As the number of bedrooms increases, the Index goes up
  - As the number of stories increase, the Index goes down.

Verifying the Anecdotal Reports

- EnergyGauge® USA v5.0.01 simulation analysis is conducted using thirteen high-efficiency home configurations in fifteen TMY3 climates
- All other things equal, the results show:
  - Significant variation in ERI/HERS by floor area (average range of 10.8 points)
  - Significant variation in ERI/HERS by number of bedrooms (average range of 7.0 points)
  - Moderate variation in ERI/HERS by number of stories (average range of 3.1 points)

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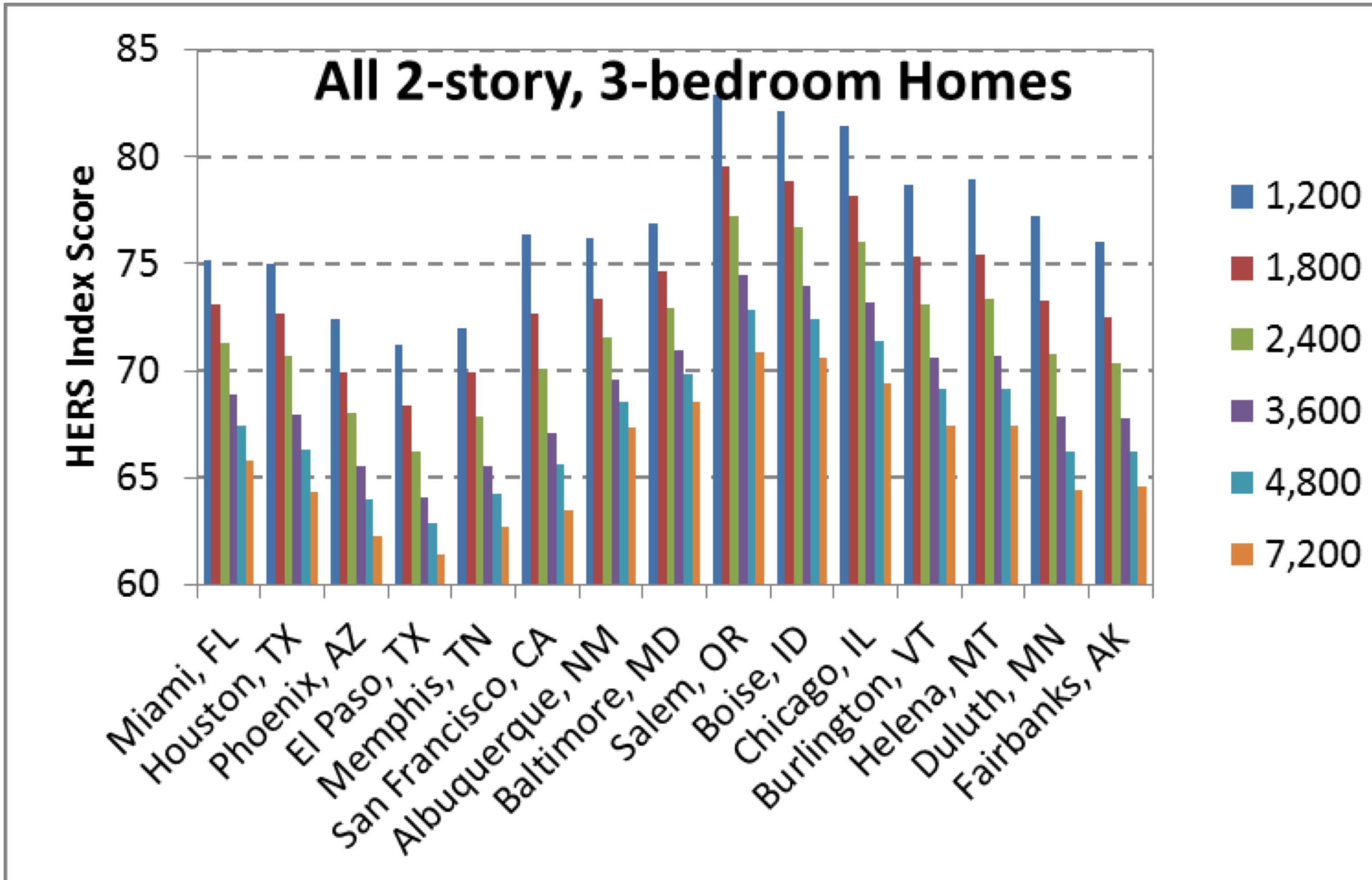
Example EnergyGauge Results: CFA



Index Adjustment Factors

- Index Adjustment Factors (IAFs) are developed to reduce the variation in HERS Index across home configurations
  - Average Index range due to floor area is reduced from 10.8 points to 2.0 points
  - Average Index range due to number of bedrooms is reduced from 7.0 points to 1.4 points
  - Average Index range due to number of stories is reduced from 3.1 points to 1.9 points

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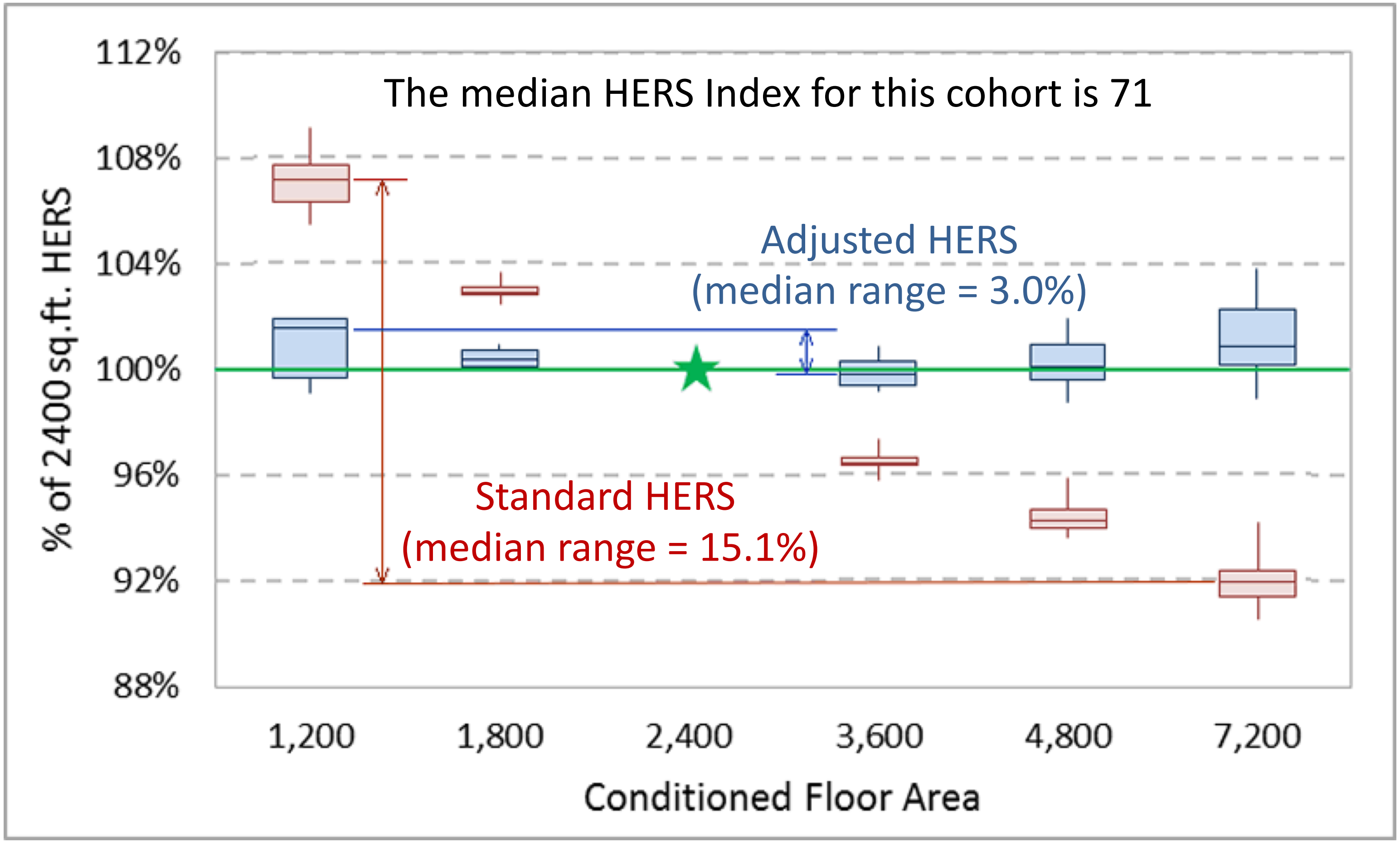
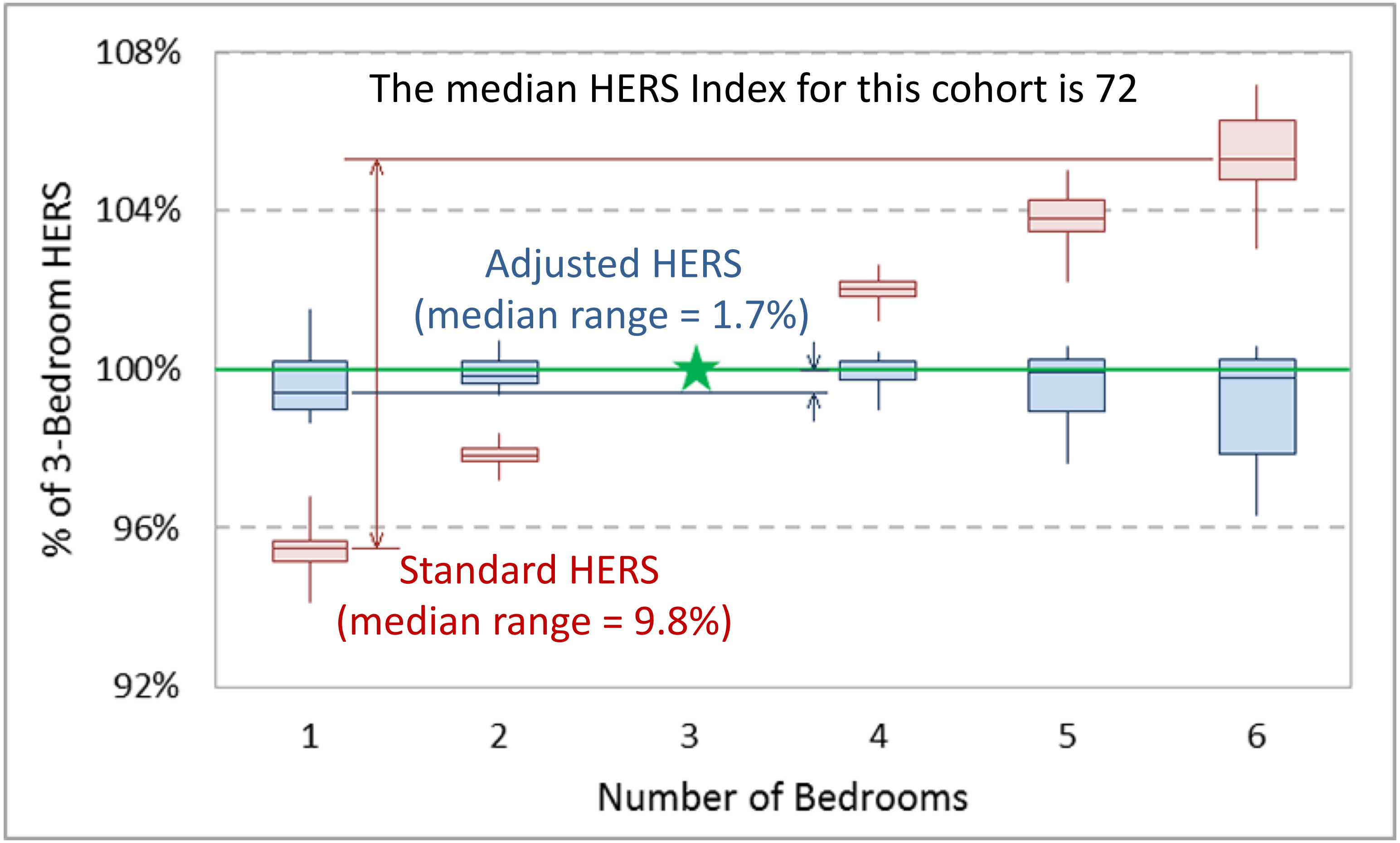
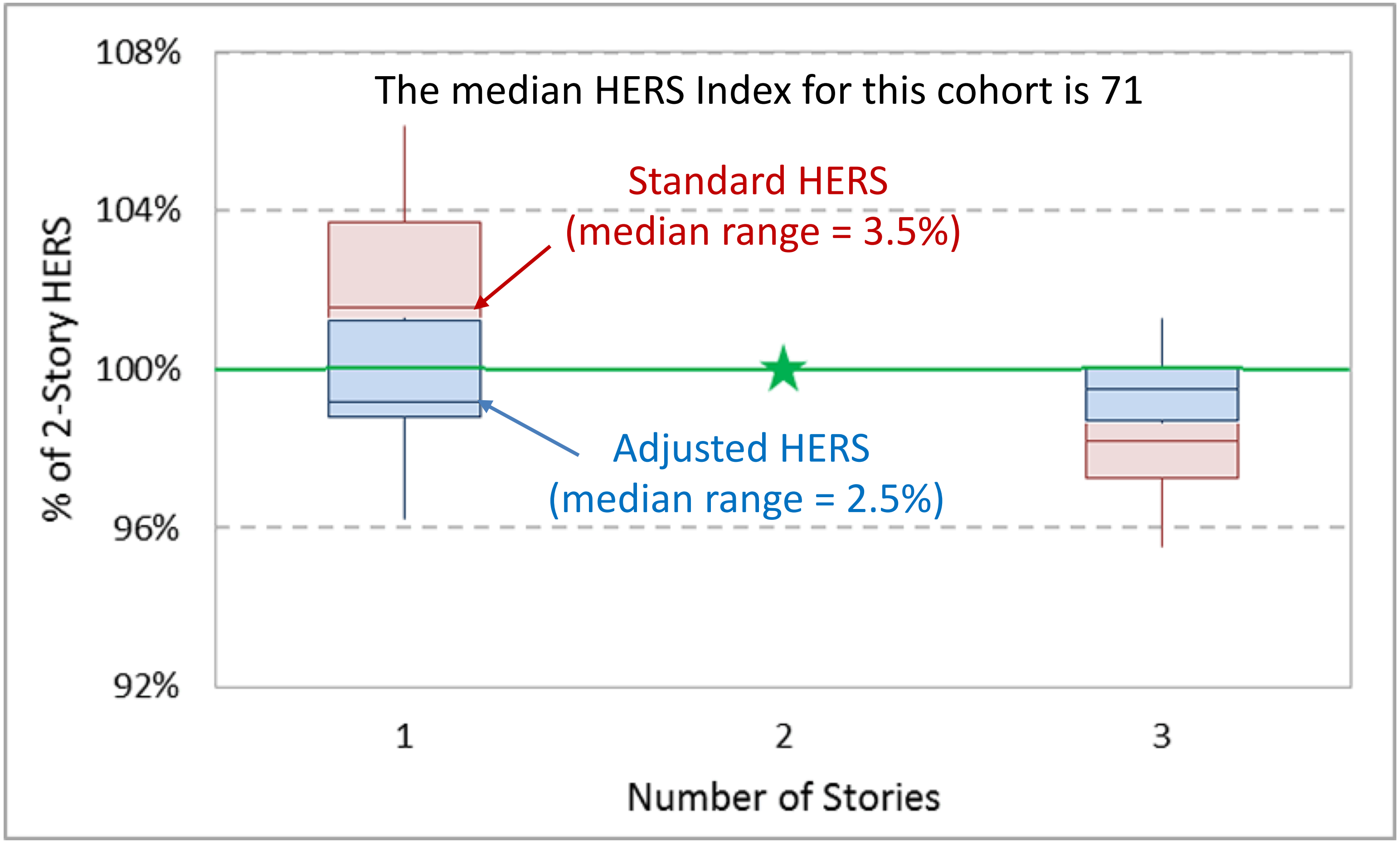
Floor Area Adjustment



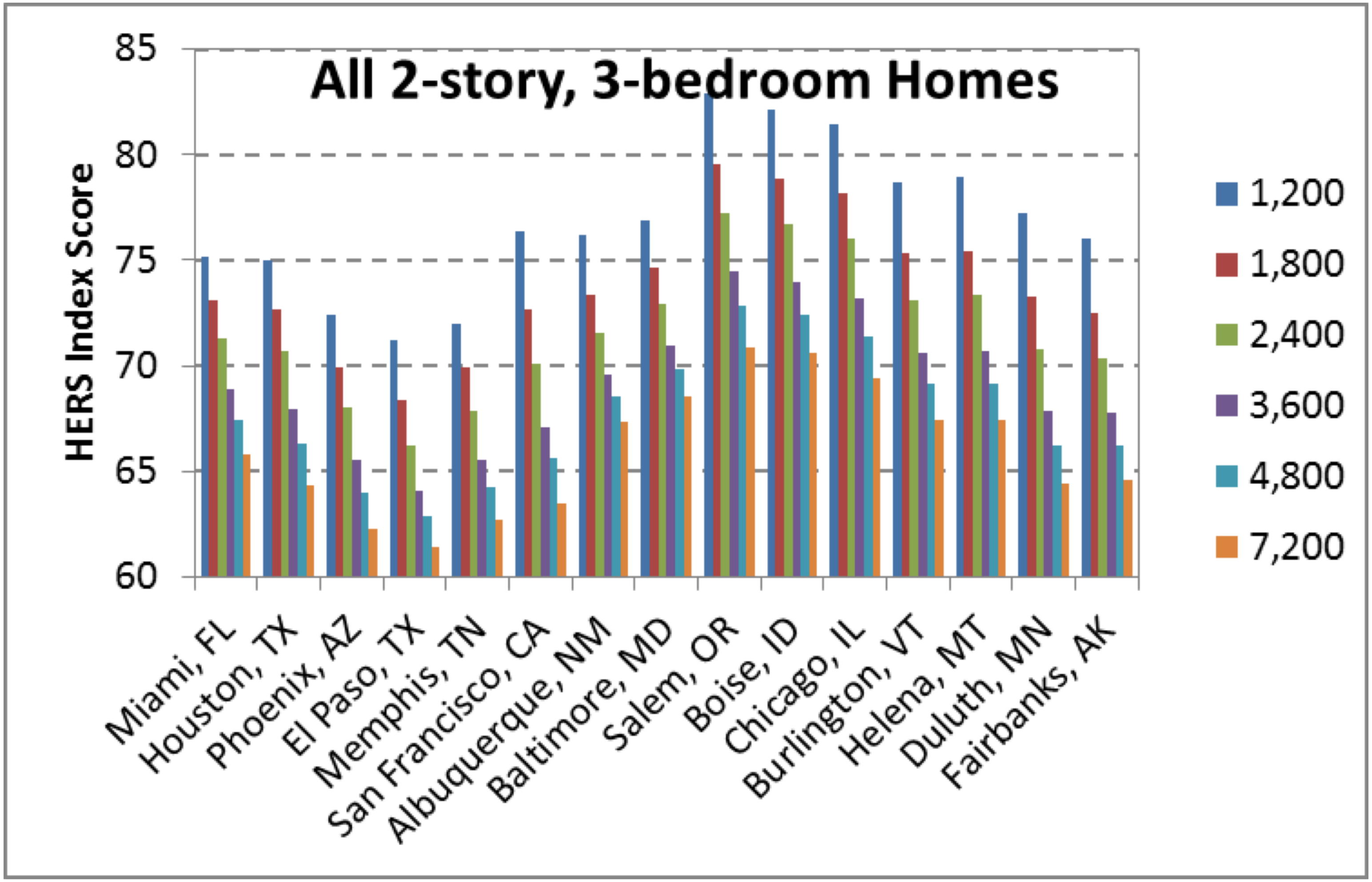
Bedrooms Adjustment



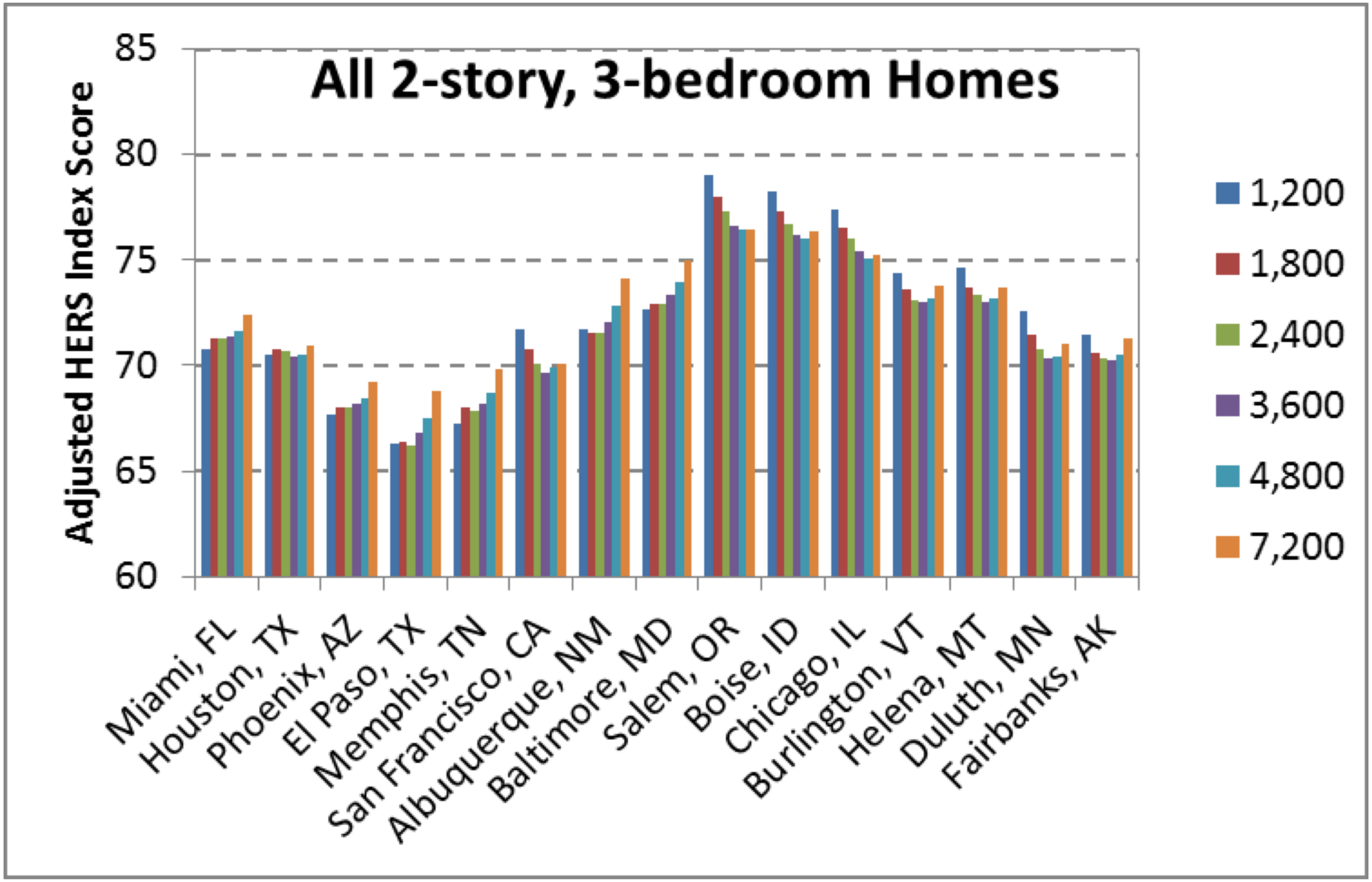
Stories Adjustment



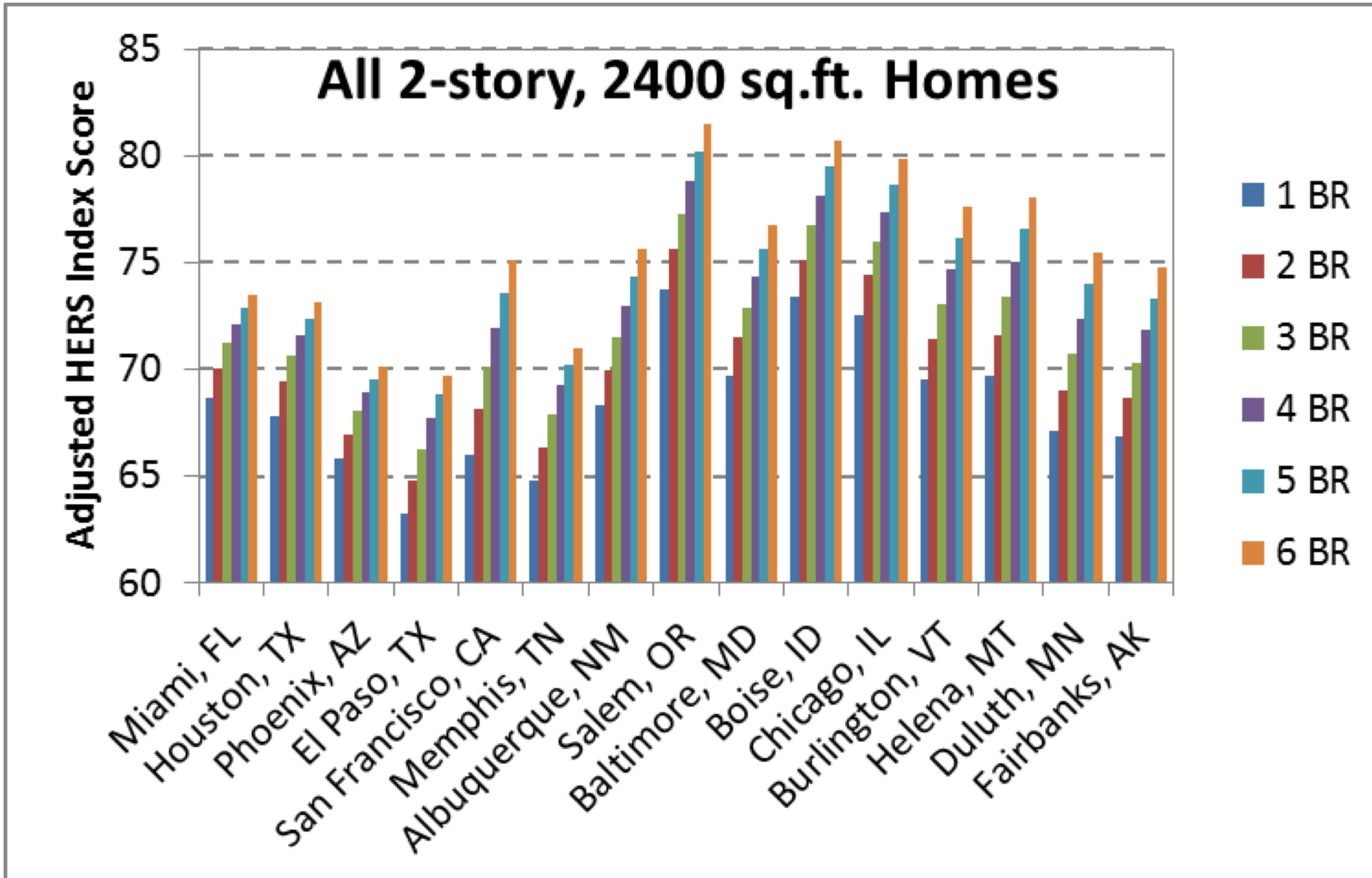
HERS Index by Floor Area



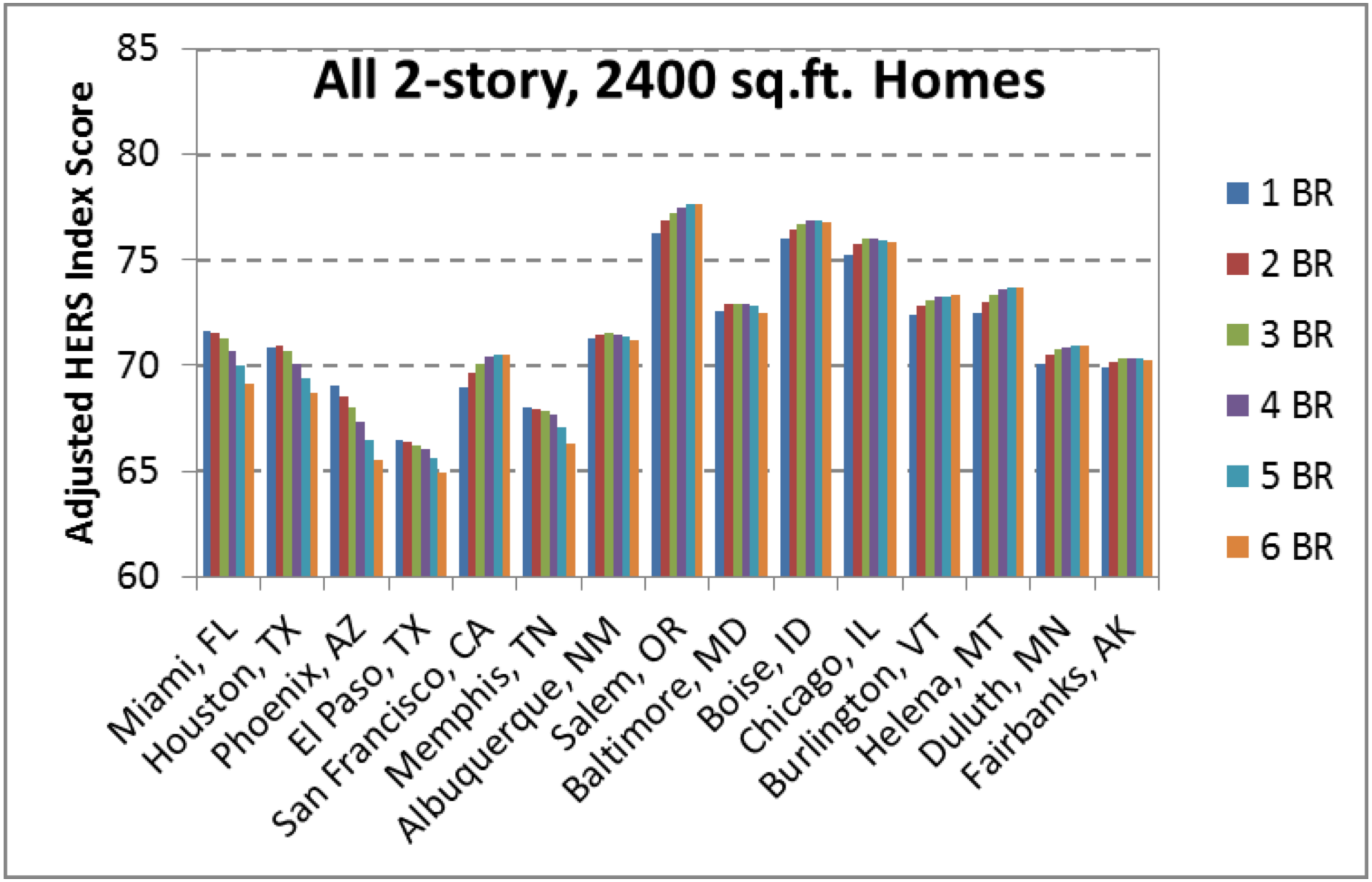
Adjusted HERS Index by Floor Area



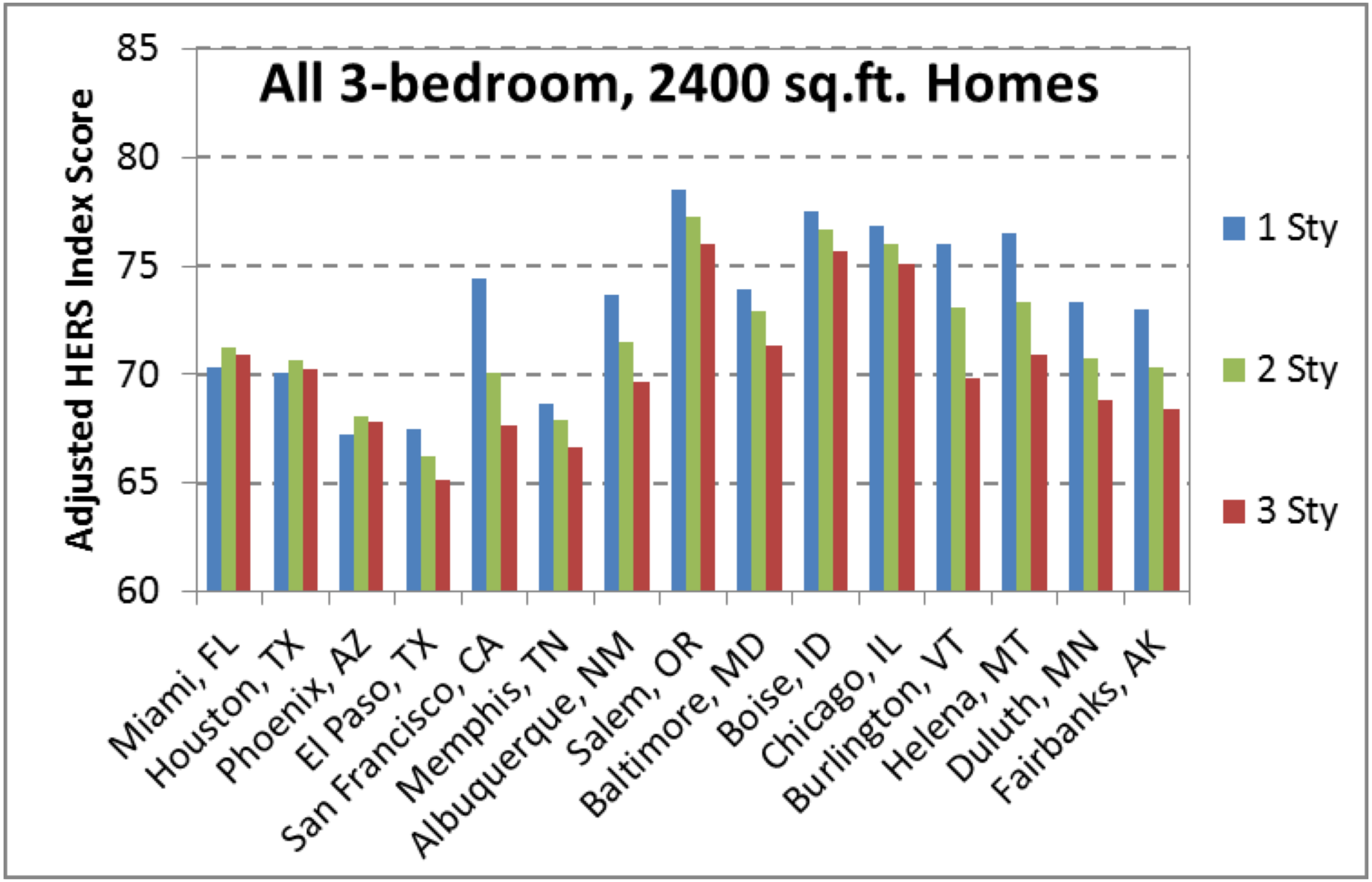
HERS Index by Bedrooms



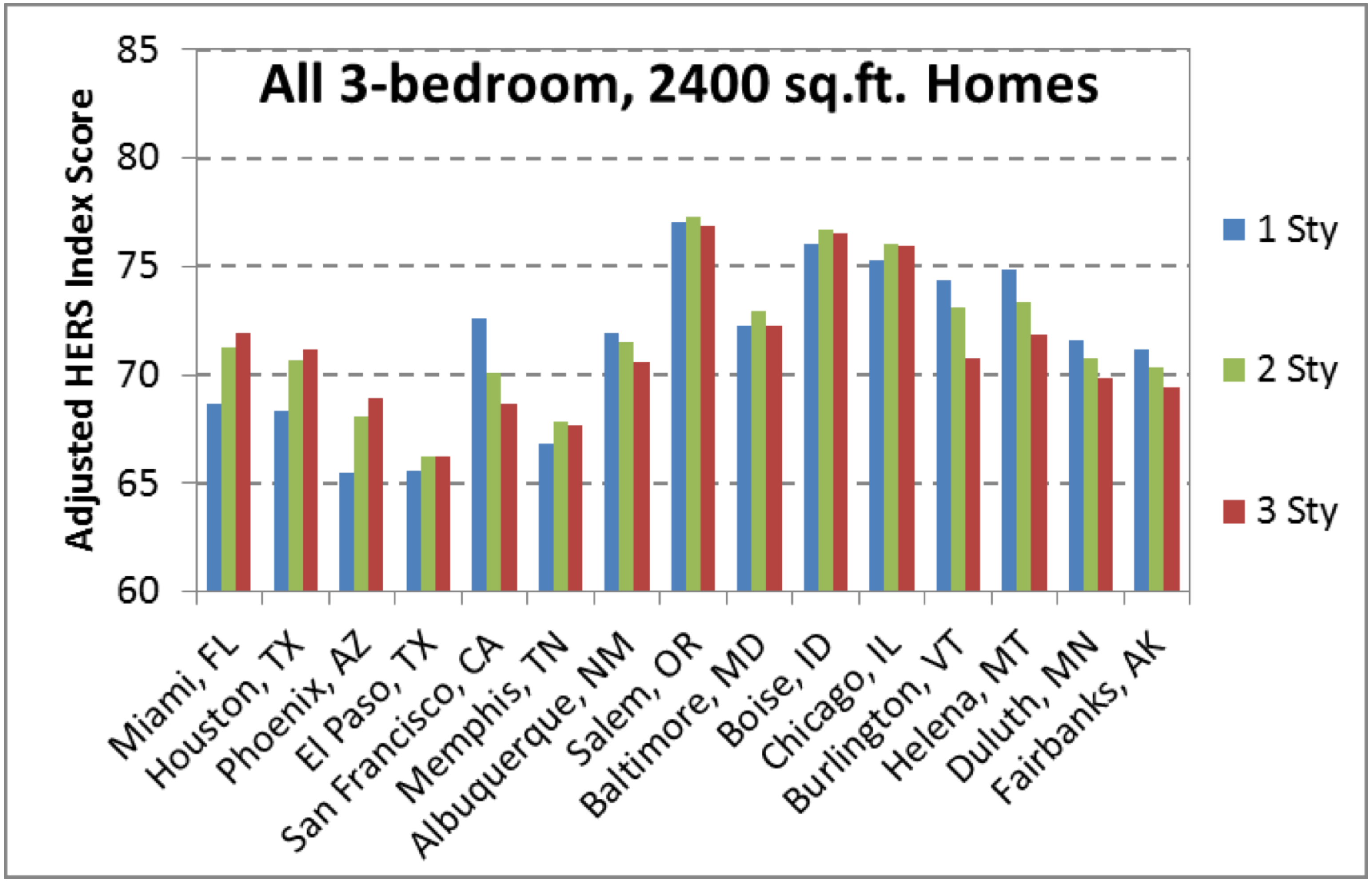
Adjusted HERS Index by Bedrooms



HERS Index by Stories



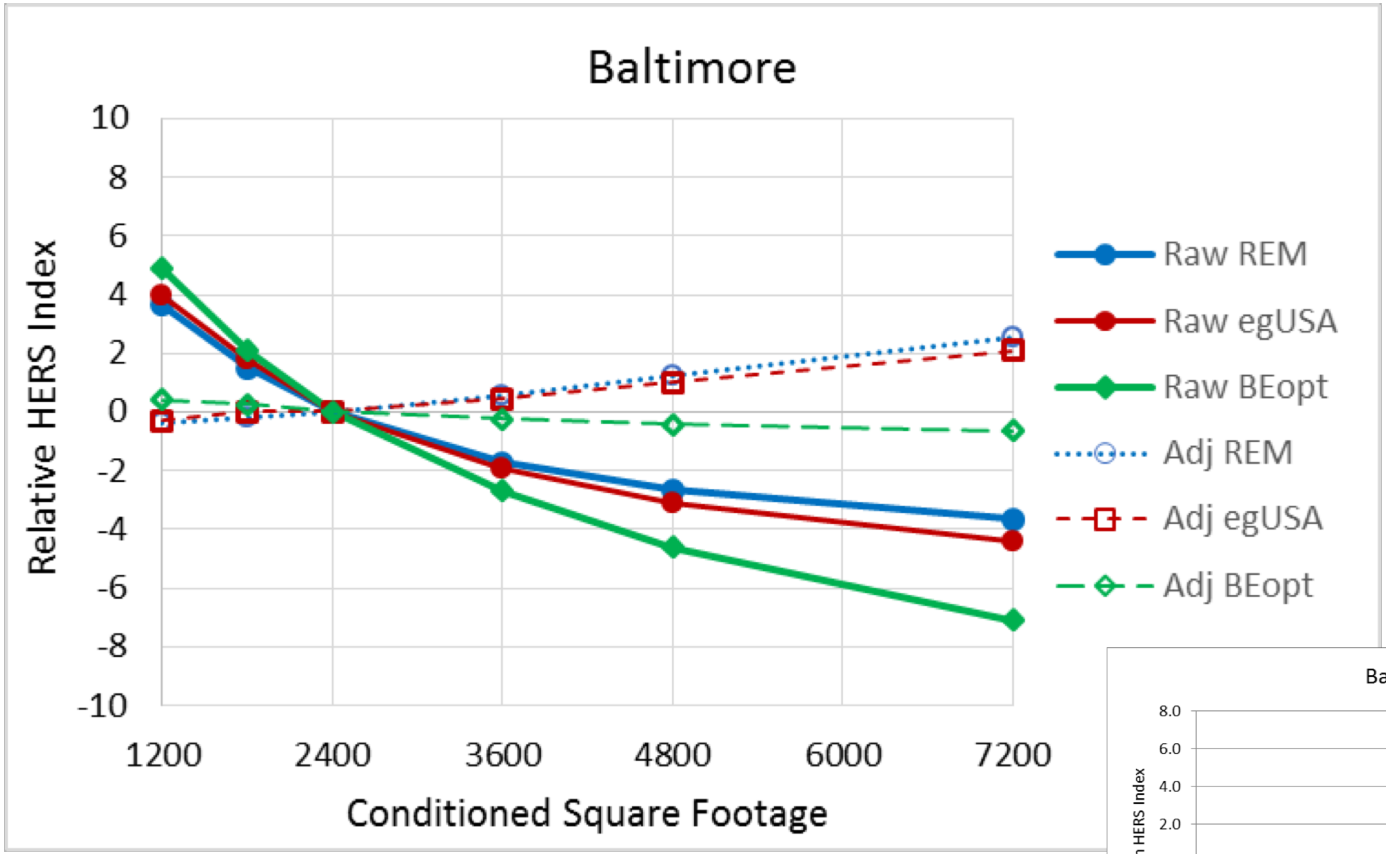
Adjusted HERS Index by Stories

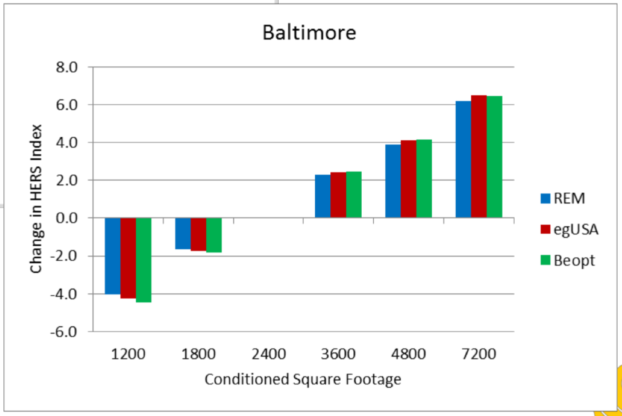


Other Software – Similar Result

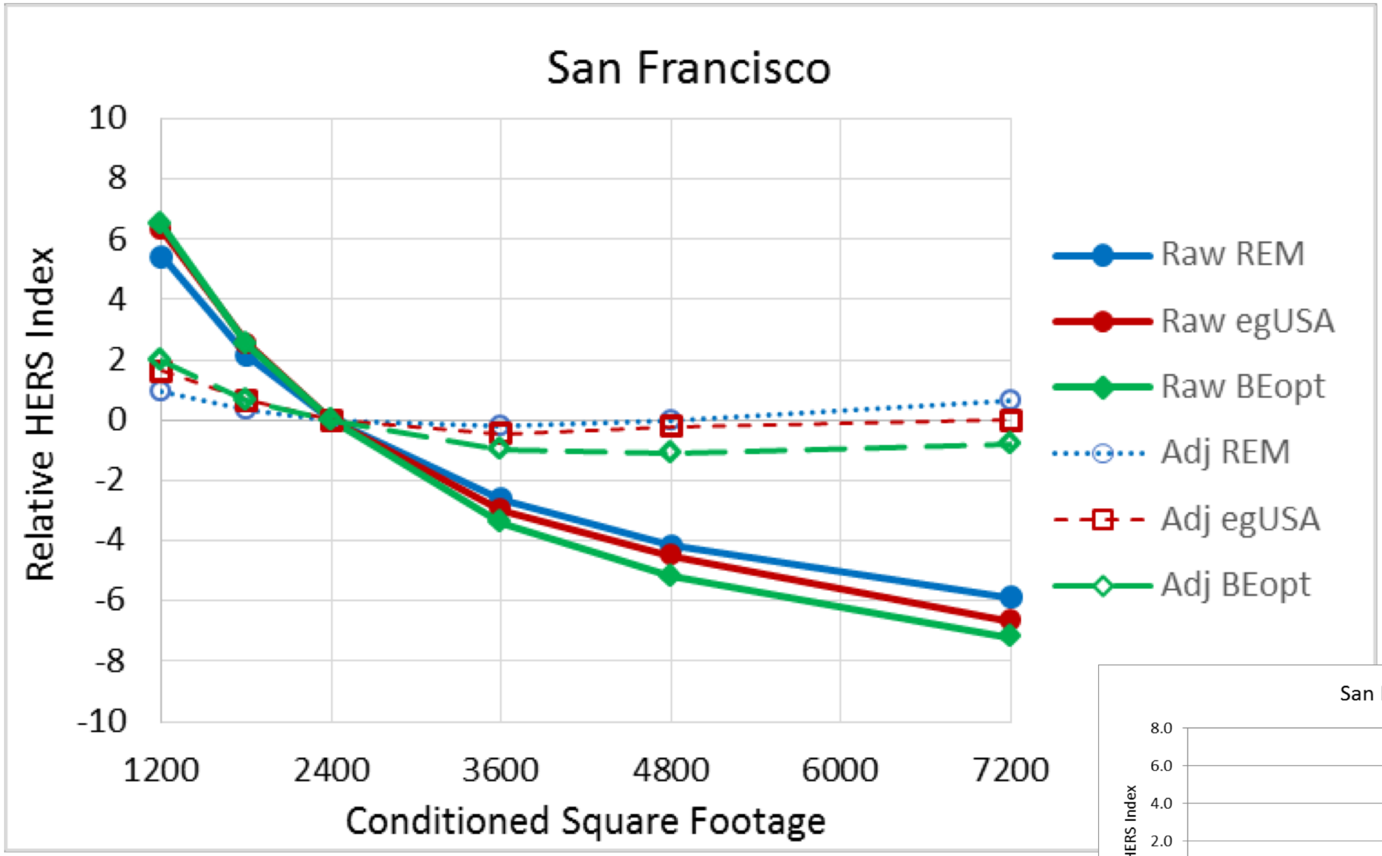
- Linda Jeng led a due diligence effort and authored a report that verified for SDC 300 that multiple software tools respond similarly to the Addendum E-2018 IAF specifications.
  - REM/Rate
  - EnergyGauge
  - BEopt

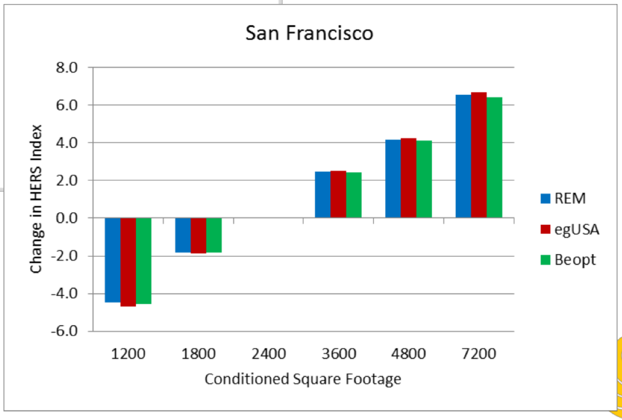
Three Software – Similar Response





Three Software – Similar Response





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Summary

- ERI/HERS simulation studies show unwarranted Index variations result from geometry and operating conditions for homes with high-efficiency envelopes
- ERI/HERS Index variations are:
  - Significant for Conditioned Floor Area (CFA)
  - Significant for number of bedrooms (Nbr)
  - Moderate for number of stories (NS)
- The proposed Addendum E Index Adjustment Factor (IAF) methodology is shown to significantly reduce ERI/HERS Index variations.

Part 1 Questions?

Part 2: Additional Technical Information For GEEKS

Analysis Methodology

- EnergyGauge® USA v.5.1 is used to simulate a cohort of 13 home configurations in 15 TMY3 cities
- All homes are configured to comply with Table R402.1.1 and all mandatory requirements of 2012 IECC
- All homes have length-to-width ratio of 1:1 (i.e. they are square)
- All homes have 15% window-floor area ratio distributed equally in four cardinal orientations
- All homes have HERS Reference Home heating, cooling, and hot water equipment
- All homes have interior air distribution systems with no air leakage
- All homes comply with ASHRAE 62.2-2013 continuous balanced whole-house mechanical ventilation requirements.

TMY3 Cities Evaluated

City, State	IECC Zone	HDD	Avg. Temp (F)	Home ACH50	62.2 wsf
Miami, FL	1A	150	76.1	5	0.41
Phoenix, AZ	2B	997	74.8	5	0.43
Houston, TX	2A	1,439	68.6	5	0.41
El Paso, TX	3B	2,499	64.4	3	0.48
San Francisco, CA	3C	2,736	56.8	3	0.60
Memphis, TN	3A	2,999	62.7	3	0.46
Albuquerque, NM	4B	4,157	56.6	3	0.54
Salem, OR	4C	4,583	53.1	3	0.55
Baltimore, MD	4A	4,631	55.8	3	0.50
Boise, ID	5B	5,395	52.2	3	0.56
Chicago, IL	5A	6,399	50.0	3	0.60
Burlington, VT	6A	7,491	46.2	3	0.61
Helena, MT	6B	7,587	44.9	3	0.63
Duluth, MN	7A	9,620	39.2	3	0.70
Fairbanks, AK	8	13,072	29.4	3	0.70

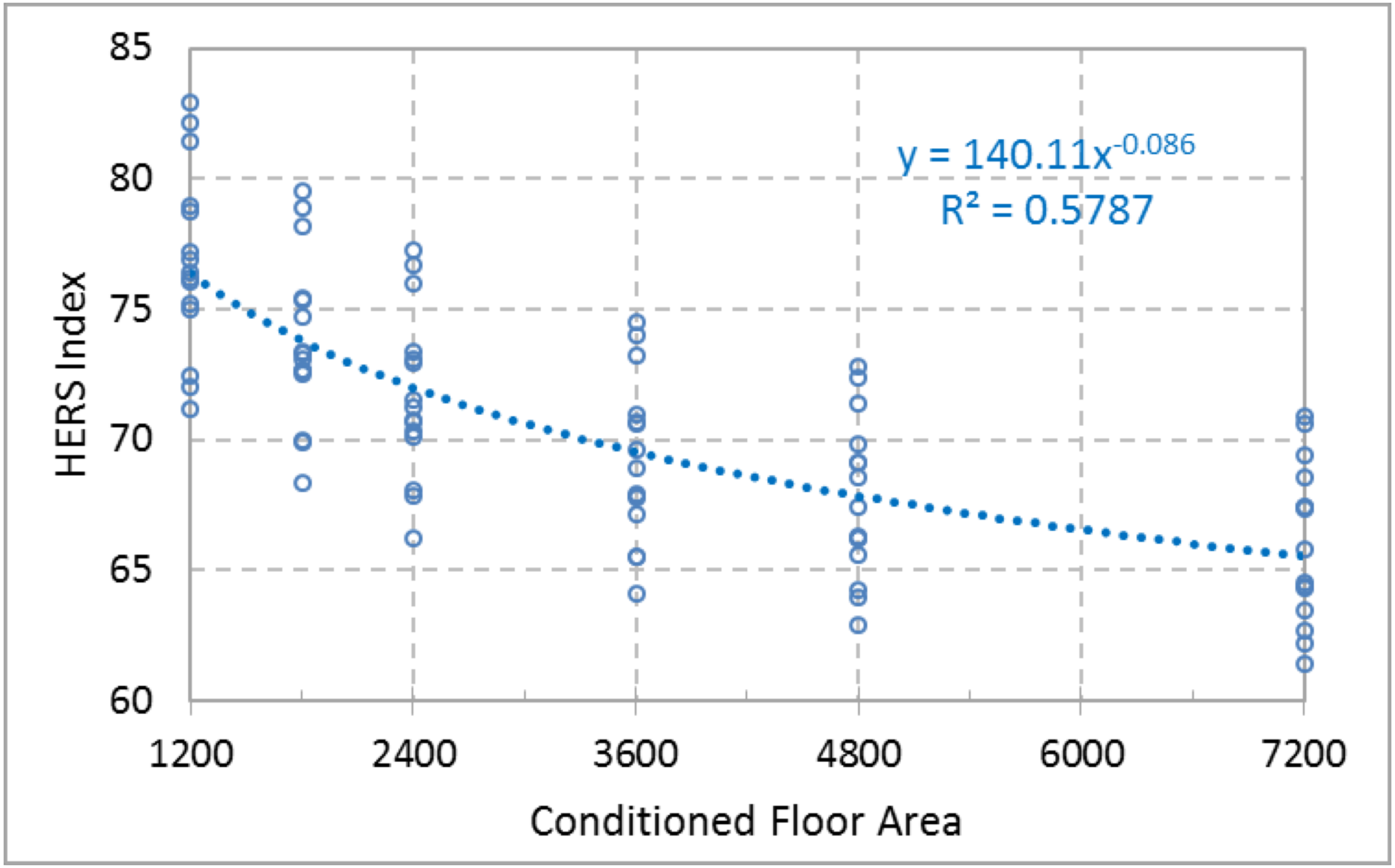
Home Geometries

- Conditioned floor areas: 1200, 1800, 2400, 3600, 4800 & 7200 square foot homes
- Number of bedrooms: 1, 2, 3, 4, 5 & 6 bedrooms for 2400 ft^2, 2-story homes
- Number of stories: 1-story, 2-story & 3-story for 2400 ft^2 homes
- Total of 13 different home configurations
- 2400 ft^2, 2-story, 3-bedroom homes serve as the baseline against which all other home configurations are compared in each city.

Normalization Procedure

- All Index scores are normalized to reduce differences across climates
  - Conditioned floor area results are normalized to the 2400 ft^2 homes (i.e. index results for all other home sizes divided by index result for 2400 ft^2 homes)
  - Number of bedrooms results are normalized to results for 3-bedroom homes
  - Number of stories results are normalized to results for 2-story homes
- Each set of normalized results is subjected to regression analysis.

HERS Regression by CFA



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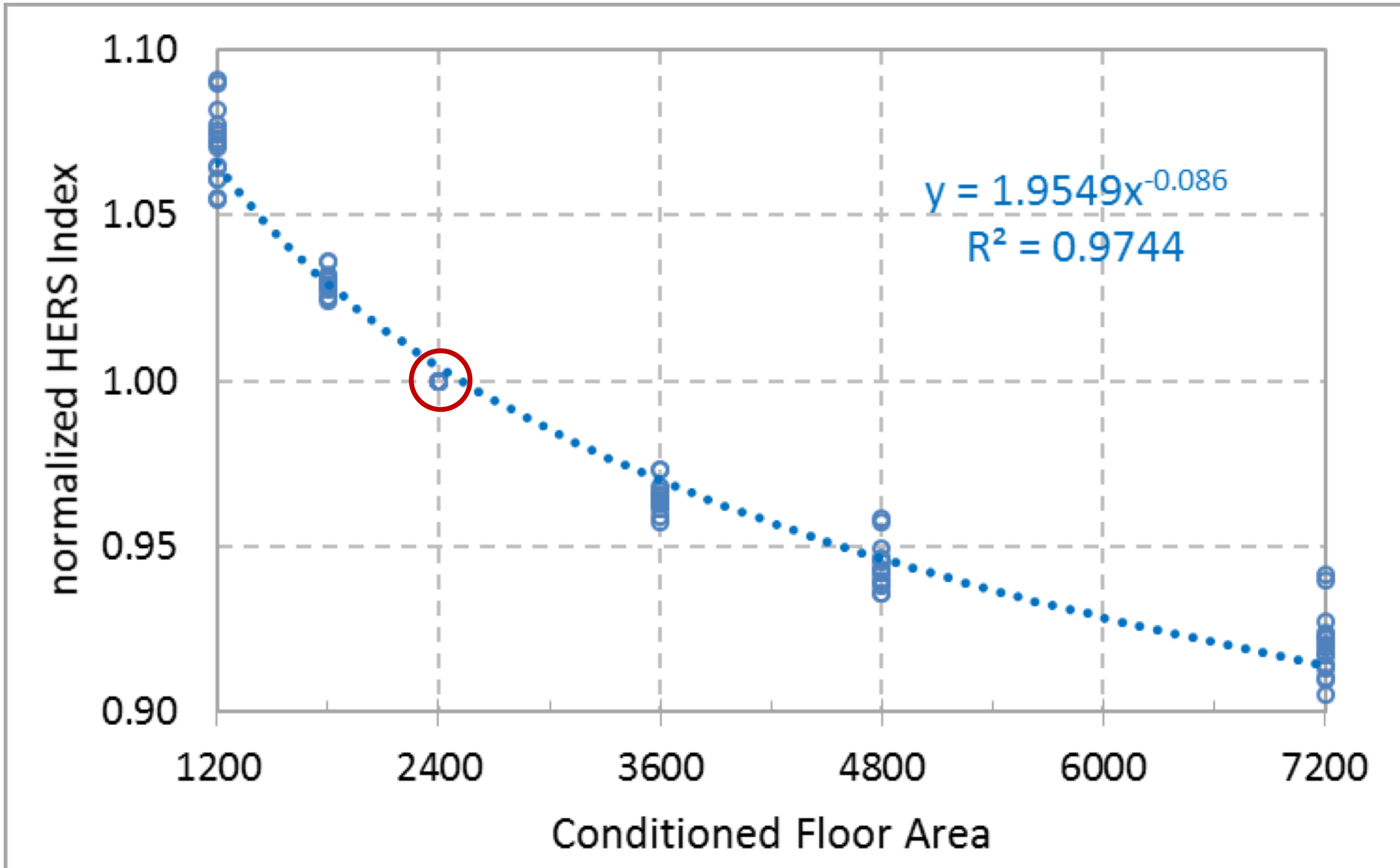
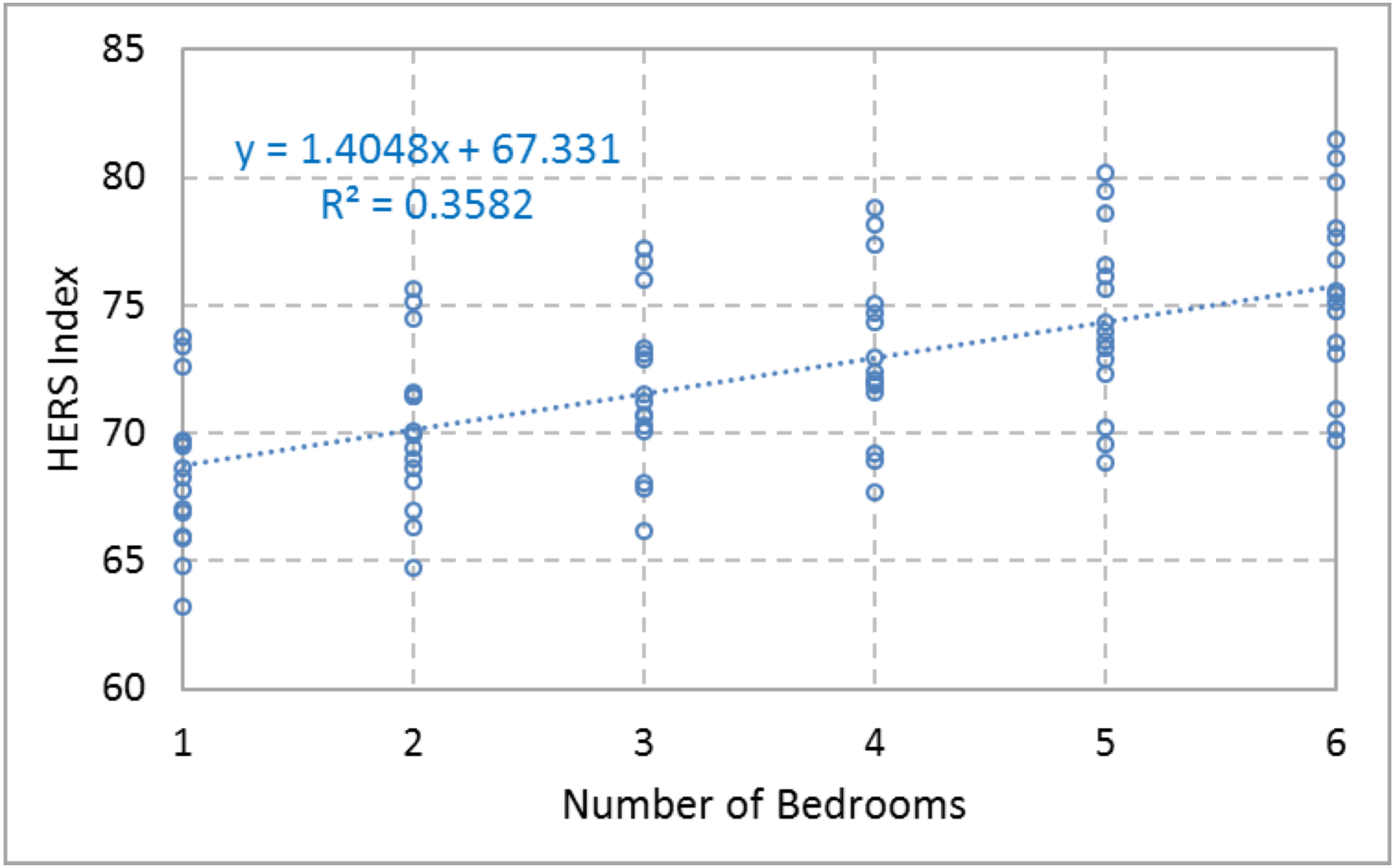
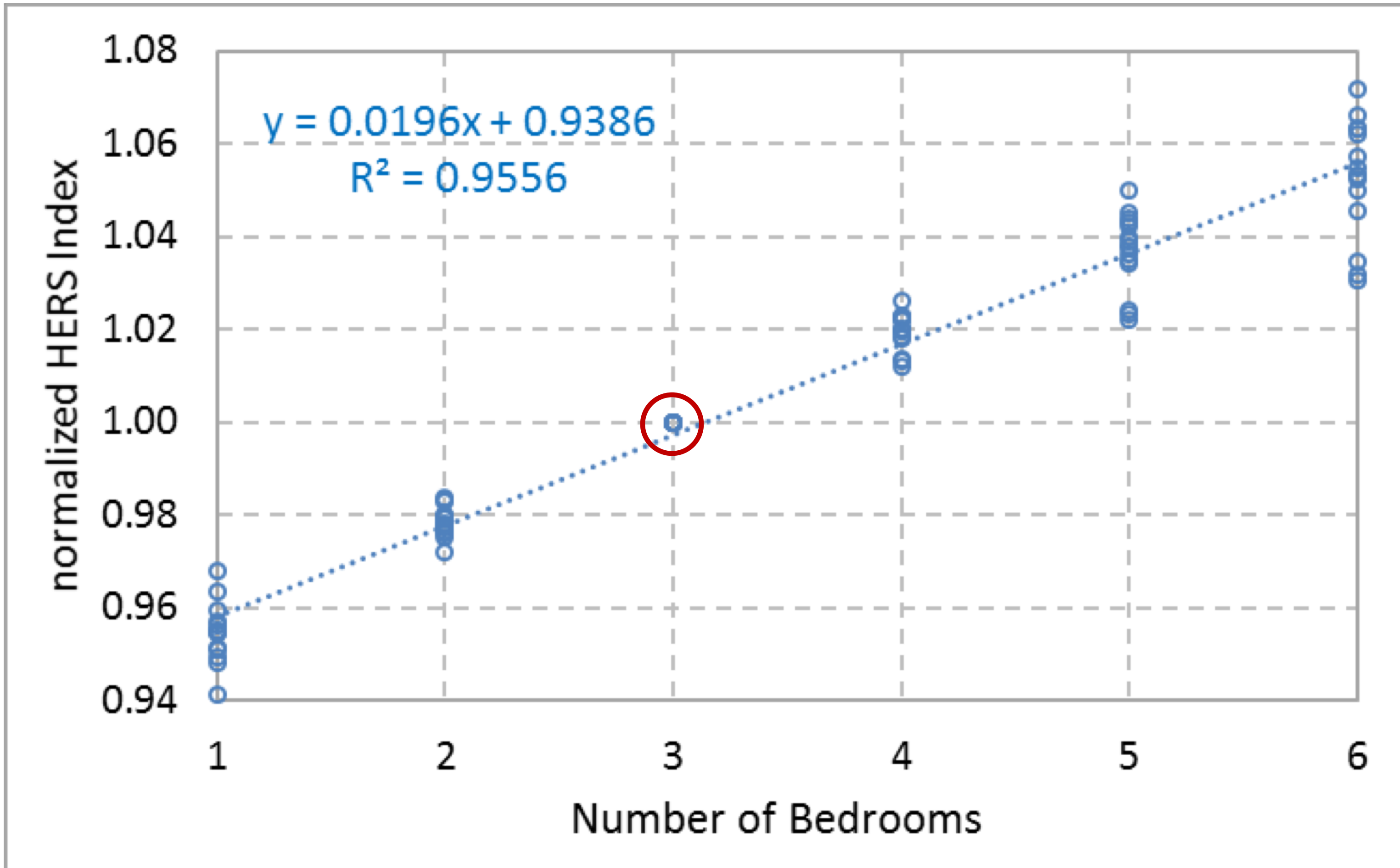
Normalized Regression by CFA



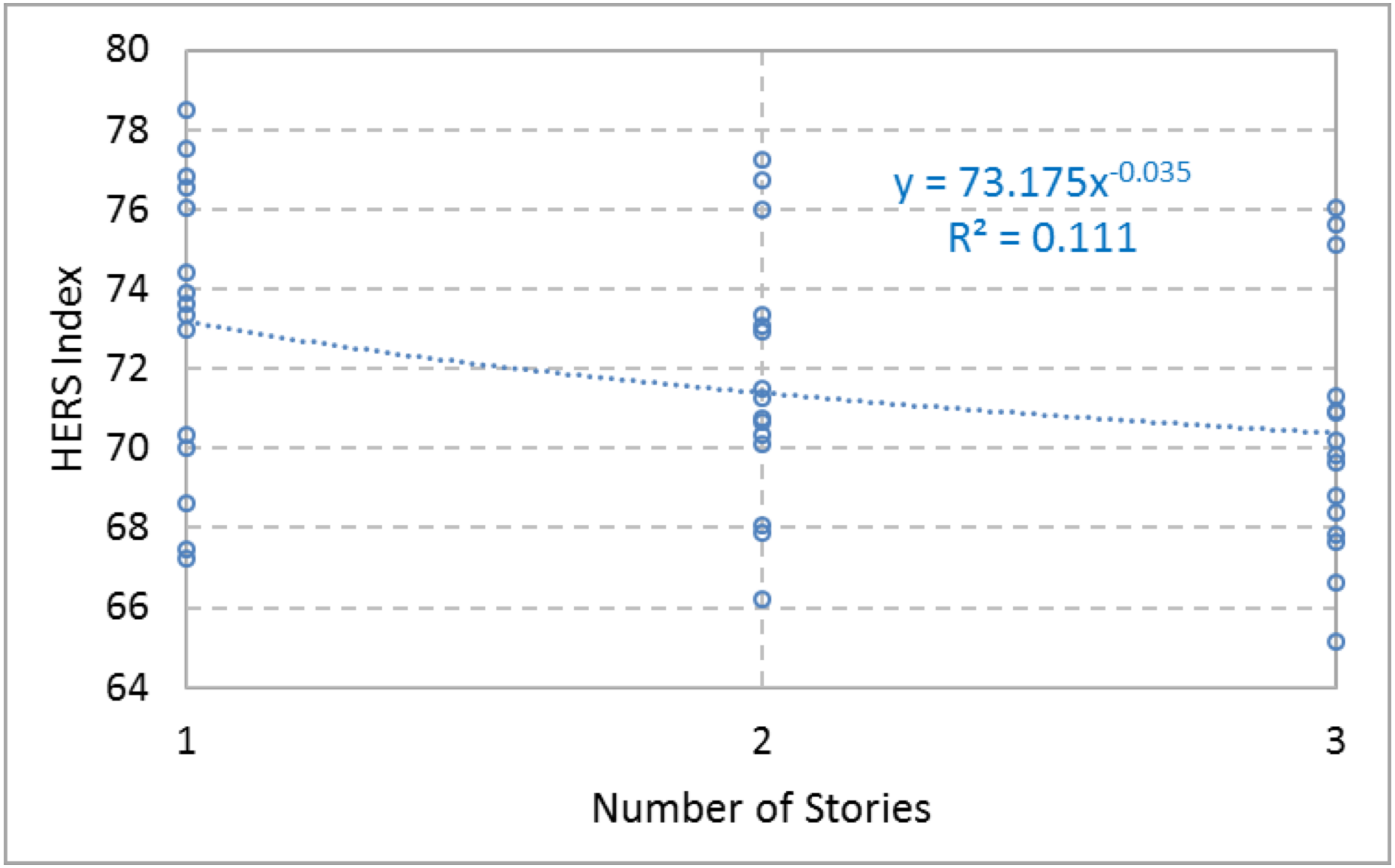
HERS Regression by Bedrooms



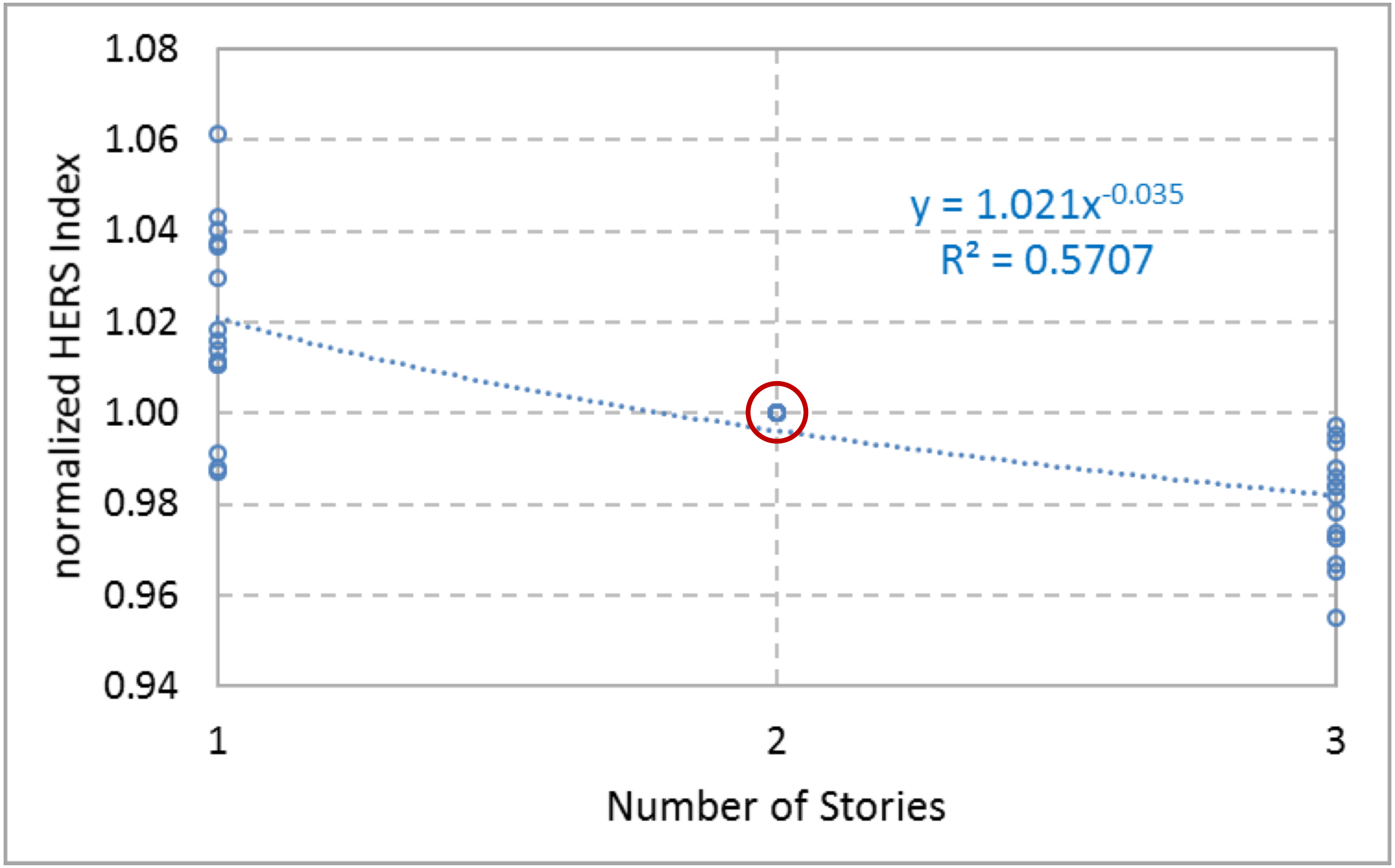
Normalized Regression by Bedrooms



HERS Regression by Stories



Normalized Regression by Stories



Index Adjustment Factor (IAF)

Based on the regression analysis and using the 2400 ft^2, 3-bedroom, 2-story home as the basis, an Index Adjustment Factor (IAF) that considers all three dependencies can be constructed as follows:

$$IAF = ((2400/CFA)^{0.086})*(1+(0.0196*(Nbr-3)))*((2/NS)^{0.035})$$

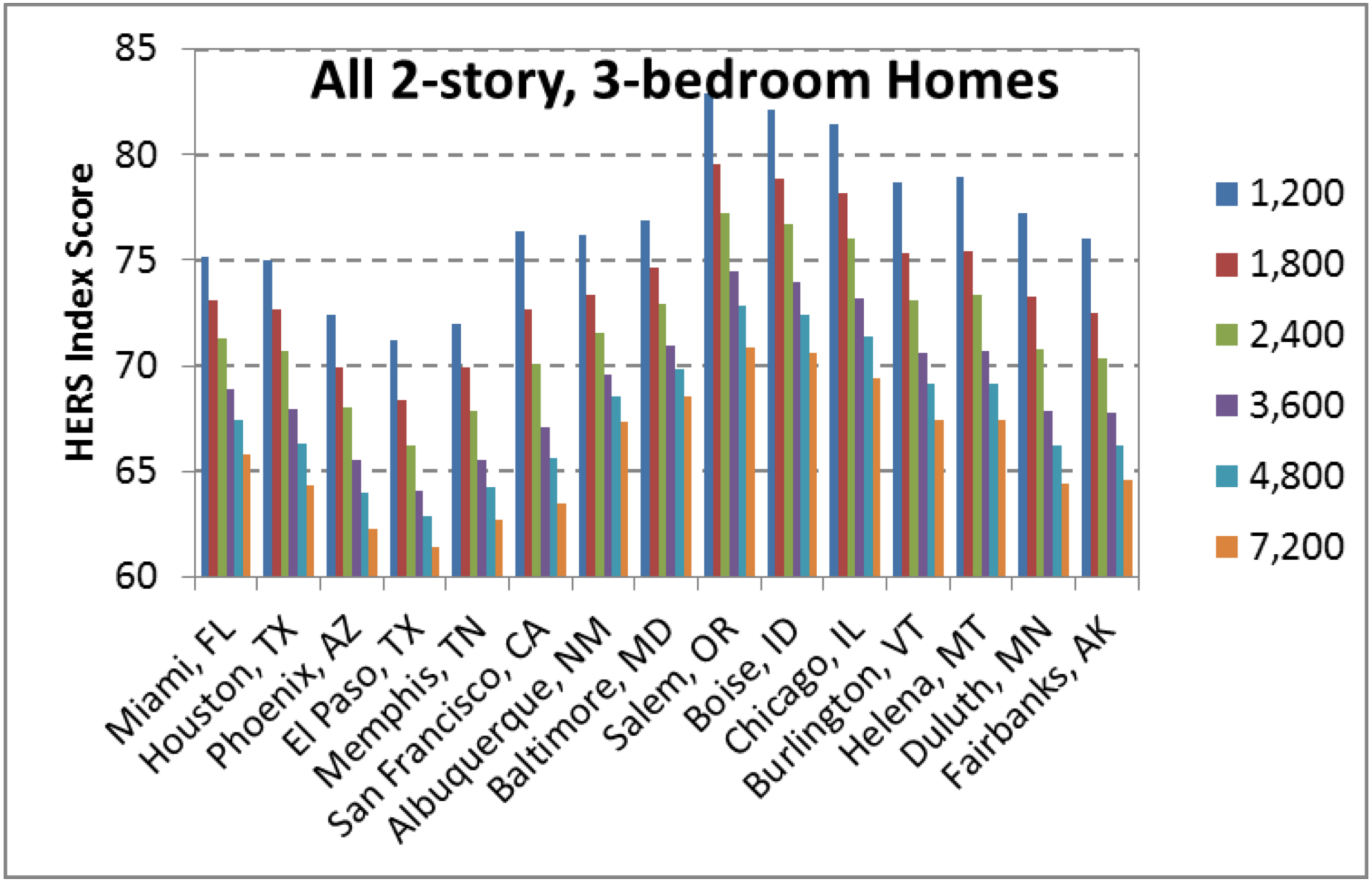
Using Index Adjustment Factors

- Index Adjustment Factor (IAF) can be used to adjust the HERS Index such that variations arising from differences in conditioned area, number of bedrooms, and number of stories, are minimized, as follows:

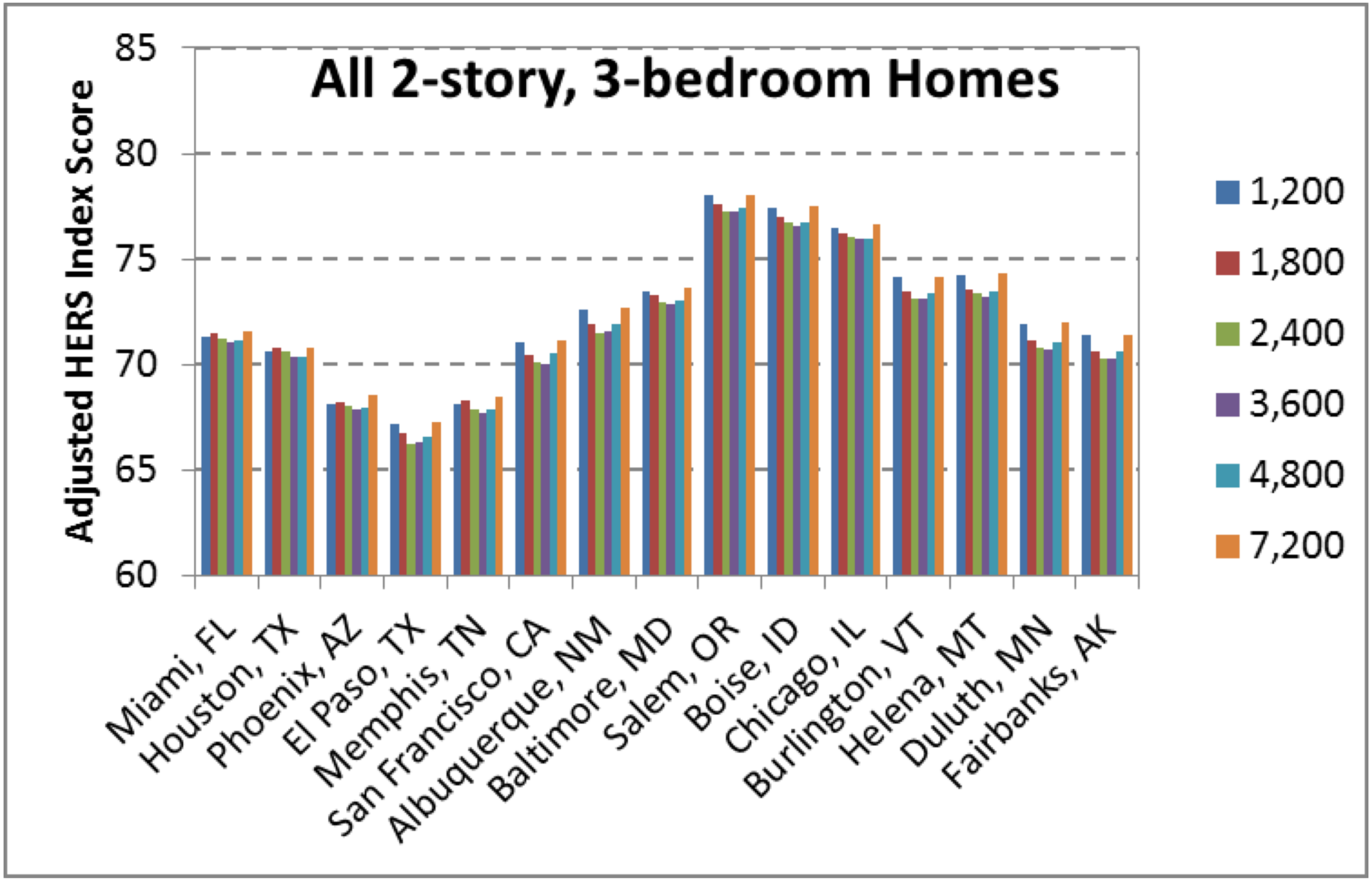
$$HERS_{adj} = HERS / IAF$$

- The impact of this adjustment is illustrated by the next two slides.

HERS Index by Floor Area



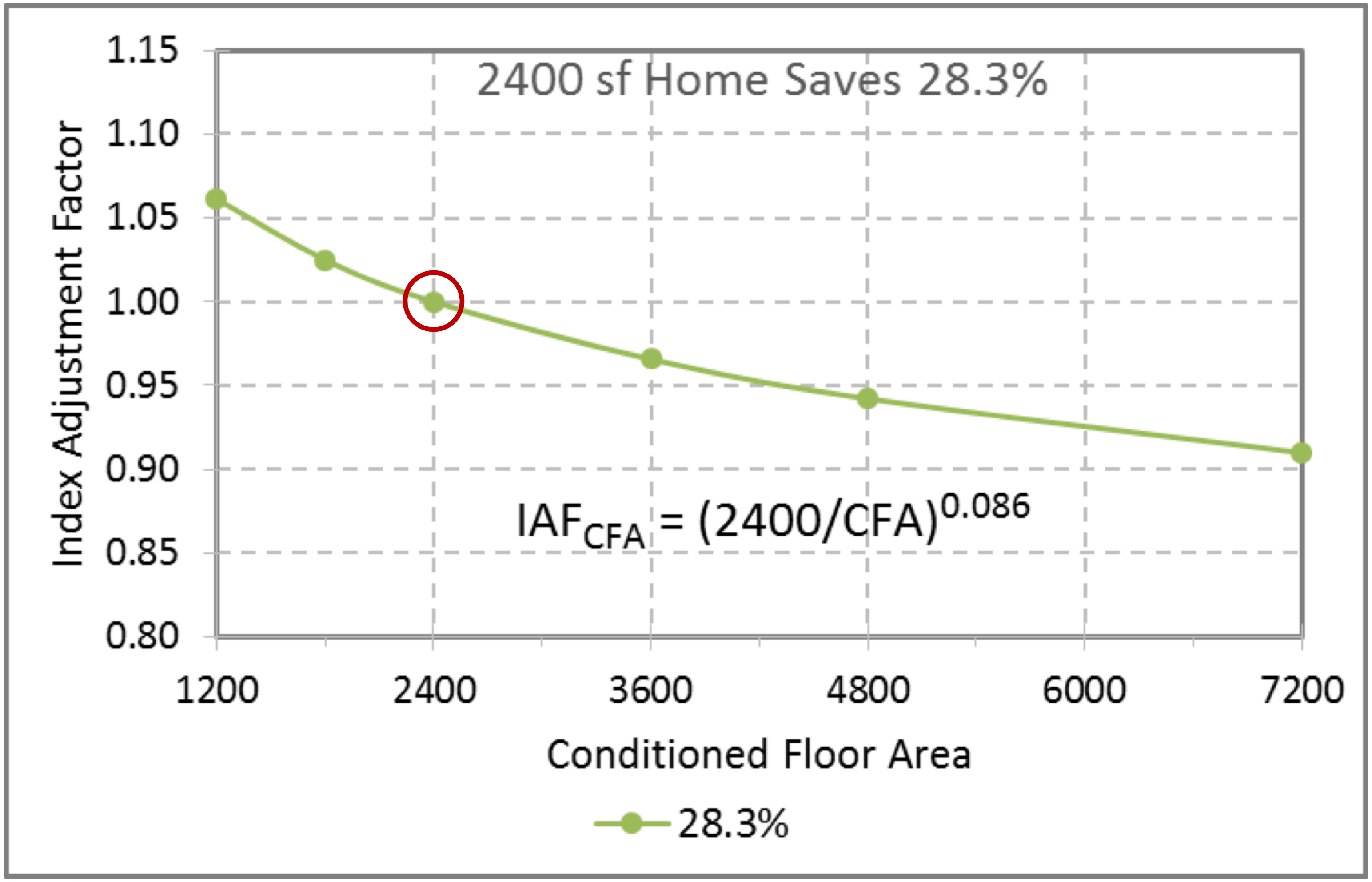
Adjusted HERS Index = HERS / IAF



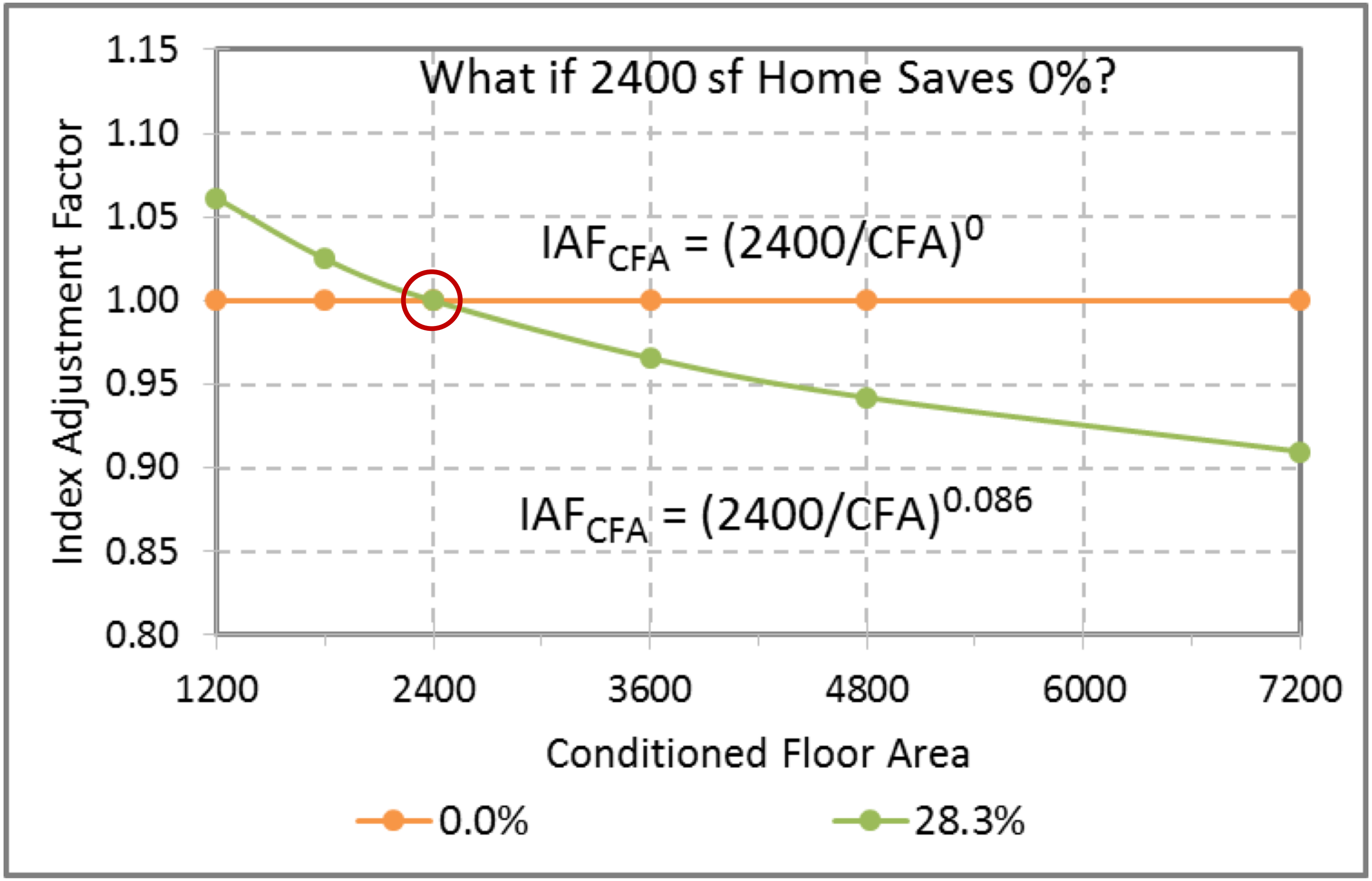
The "Drumheller Corollary" . . .

- If a Rated Home achieves no savings compared to the Reference Home, its Index should be 100 in all cases? (i.e. the Index Adjustment Factor should be 1.00)
- If a home achieves greater savings than the 2012 IECC homes used in this analysis, the Index Adjustment Factor curve should be steeper
- If a home achieves less savings than the 2012 IECC homes used in this analysis, the Index Adjustment Factor curve should be shallower.

Index Adjustment Curve for CFA



Adjusting The Curve



“Relative” Adjustment Factors

- Concept: Make the Index Adjustment Factor relative to the savings over the Reference Home achieved by the square, 2400 ft^2, 2-story, 3-bedroom Index Adjustment Design (IAD)
- The exponent for 28.3% savings is 0.086
- Thus, the “relative” adjustment exponent would be:

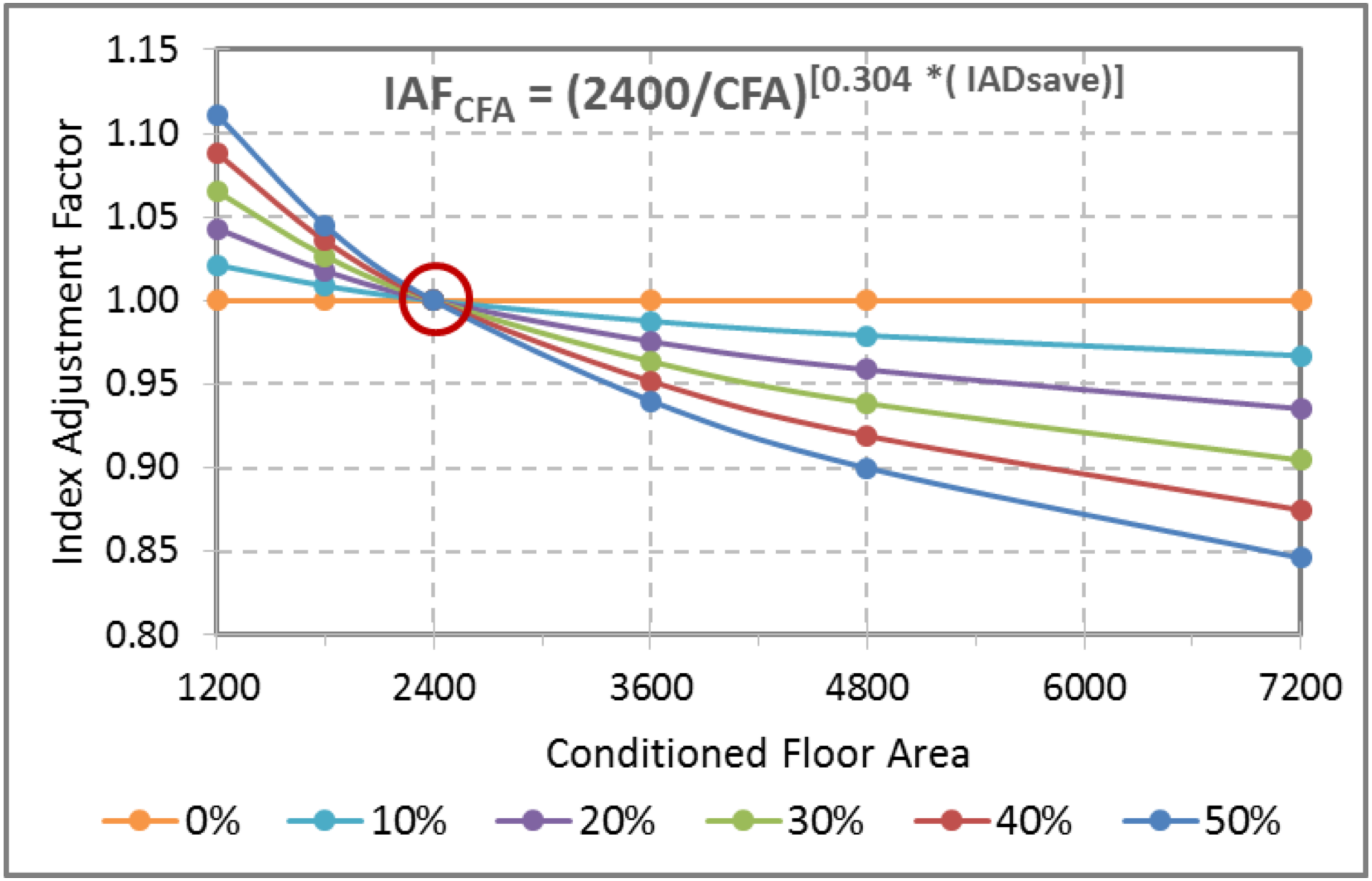
  0.086/0.283 = 0.304 per % savings
- And the “relative” adjustment exponent becomes:

  $[0.304 * (IAD_{SAVE})]$

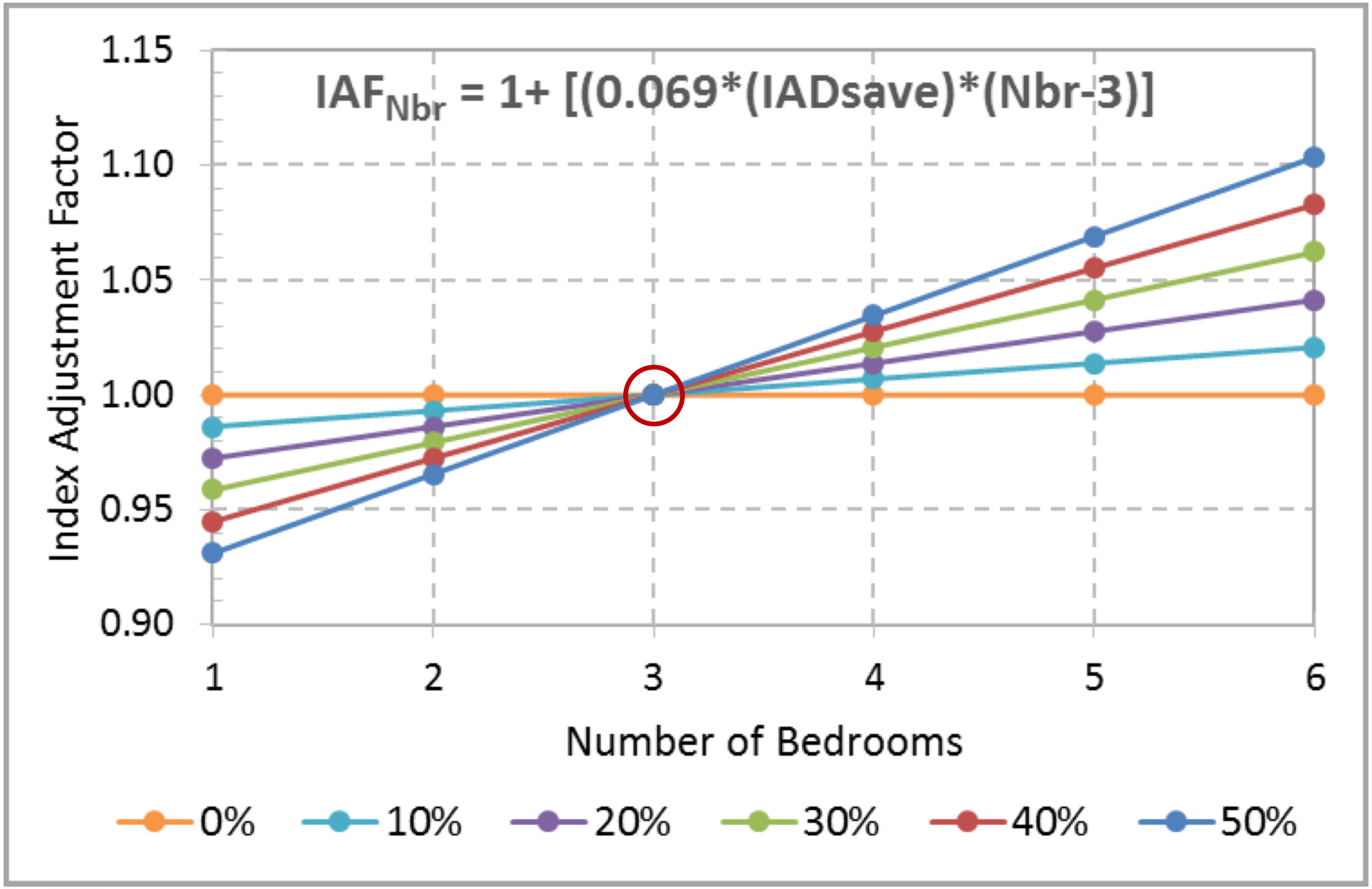
  where

  $IAD_{SAVE} = [100 – (ERI_{IAD})] / 100$

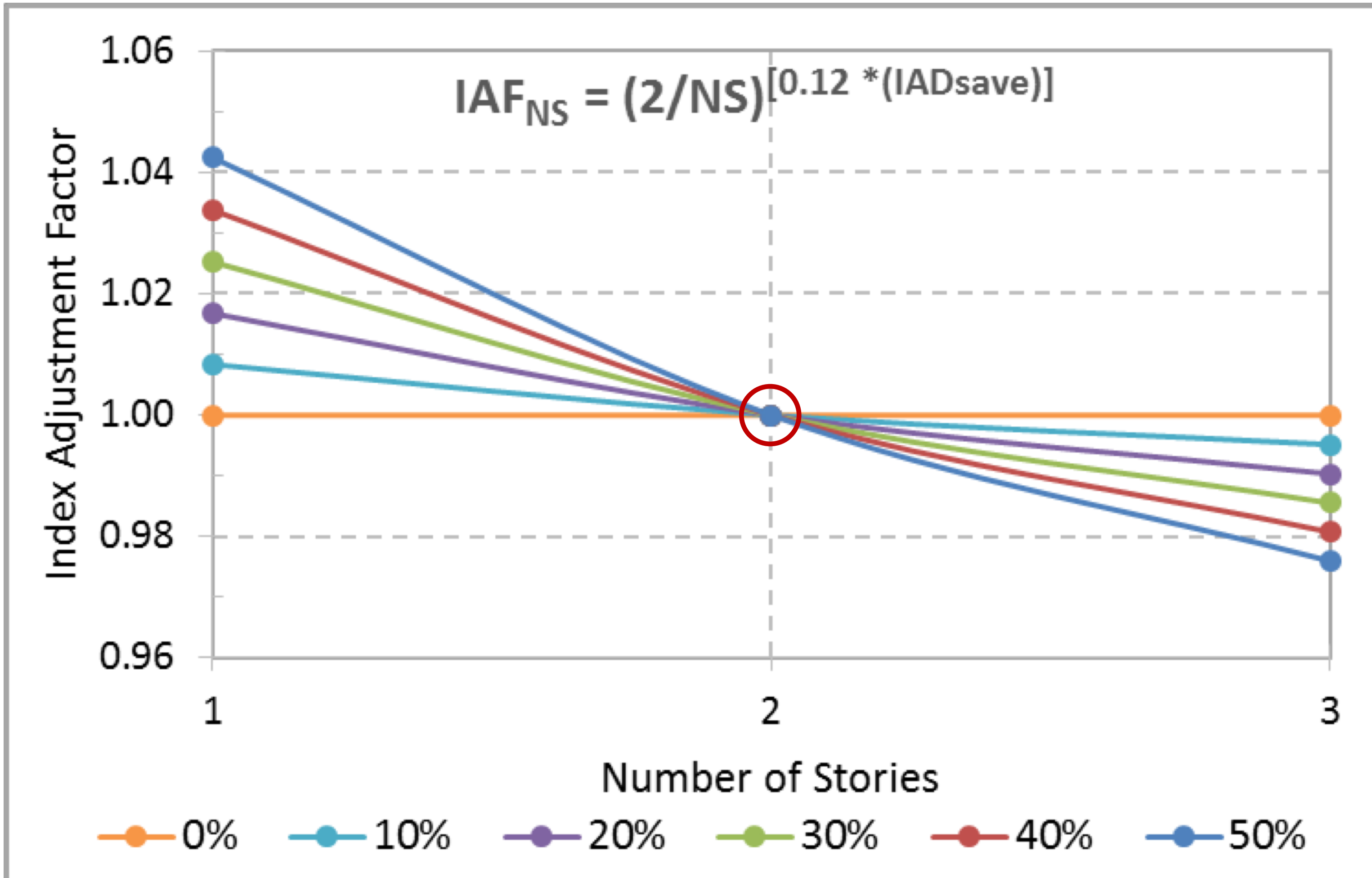
Relative IAF: Floor Area (CFA)



Relative IAF: Bedrooms (Nbr)



Relative IAF: Stories (NS)



Addendum E-2018

The Index Adjustment Factor (IAF) accounts for the comparative savings (IAD_{SAVE}) over the Reference Home achieved by a square, 2400 ft^2, 2-story, 3-bedroom Index Adjustment Design (IAD) having the same envelope attributes as the Rated Home but using the Reference Home standard equipment, where the overall Rated Home IAF_{RH} is as follows:

$$IAF_{RH} = IAF_{CFA} * IAF_{Nbr} * IAF_{NS}$$

where:

$$IAF_{CFA} = (2400/CFA)\text{^}(0.304*IAD_{SAVE})$$

$$IAF_{Nbr} = 1+ [0.069 * IAD_{SAVE} * (Nbr-3)]$$

$$IAF_{NS} = (2/NS)\text{^}(0.12*IAD_{SAVE})$$

and where:

$$IAD_{SAVE} = (100 – ERI_{IAD}) / 100$$

IAF Implementation

- Standard ERI equation:

$$ERI = PEfrac*[TnML/TRL]*100$$

- IAF implementation:

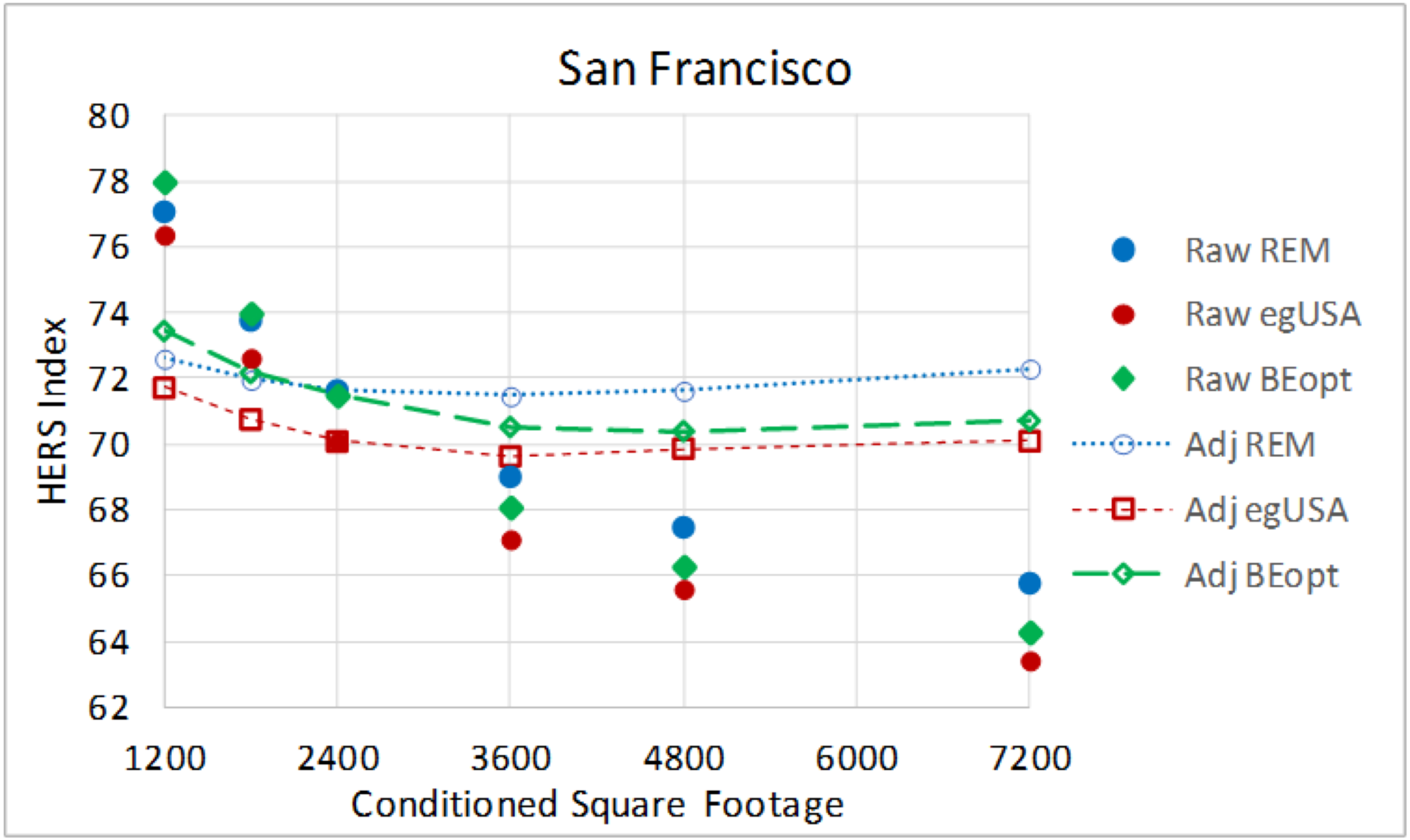
$$ERI = PEfrac*[TnML/(TRL*IAF_{RH})]*100$$

- Adjusts the Reference Home building load rather than adjusting result of entire Index calculation
- Preserves normalized Modified End Use Load calculations and on-site power production – i.e. purchased energy fraction (PEfrac) calculated in the same way with the same impact on results.

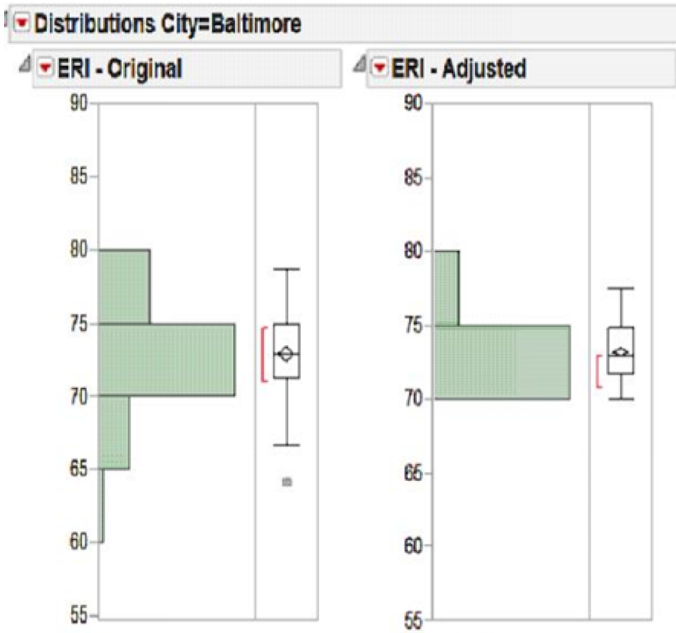
Software Tool Due-Diligence

- Results from three software tools are compared
  - REM/Rate v15.1
  - BEopt v2.6
  - EnergyGauge v5.1
- Two climates with the most divergent regression results used in the analysis
  - Baltimore, MD
  - San Francisco, CA
- Floor area, number of bedrooms and number of stories examined.

Example Results by Software Tool



Software Tool Statistics



ERI - Original

Quantiles

Summary Statistics

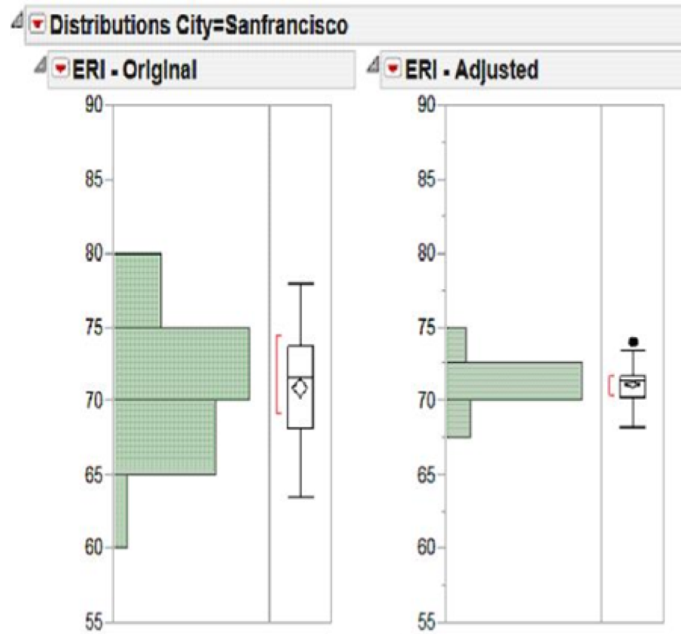
Mean	72.927273
Std Dev	3.0353749
Std Err Mean	0.2641955
Upper 95% Mean	73.449914
Lower 95% Mean	72.404631
N	132

ERI - Adjusted

Quantiles

Summary Statistics

Mean	73.182727
Std Dev	1.7502637
Std Err Mean	0.1523409
Upper 95% Mean	73.484094
Lower 95% Mean	72.881361
N	132



ERI - Original

Quantiles

Summary Statistics

Mean	70.912273
Std Dev	3.5635758
Std Err Mean	0.3101695
Upper 95% Mean	71.525862
Lower 95% Mean	70.298684
N	132

ERI - Adjusted

Quantiles

Summary Statistics

Mean	71.133409
Std Dev	1.1689787
Std Err Mean	0.1017465
Upper 95% Mean	71.334688
Lower 95% Mean	70.93213
N	132

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Across All Software Tools

- For all calculation software tools and building factors studied, the proposed Index Adjustment Factor (IAF) methodology reduced the variability of the ERI / HERS Index.
- After adjustment, the average ERI / HERS Index is changed by < 0.4% (0.35% for Baltimore and 0.31% for San Francisco)
- Sample standard deviation is reduced by more than 40% by adjustment (42% for Baltimore and 53% for San Francisco).

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Part 2 Questions?