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# HERS Index in IECC Compliance

## *Comparing the new ERI path to the traditional performance path*

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# Background

- ▶ 2015 IECC added a new Energy Rating Index (ERI) compliance path
  - ERI definition is loose but consistent with the HERS Index
  - Includes 2009 IECC “backstops” to limit the extent of tradeoffs
  - Otherwise allows trading off all house elements included in a typical HERS Index
  
- ▶ Popularity of RESNET’s HERS makes it the likely candidate ERI for many/most builders using the ERI path

Climate Zone	2015 IECC ERI Threshold
1	52
2	52
3	51
4	54
5	55
6	54
7	53
8	53



# Background – Why an analysis of ERI vs Simulated Performance Alternative?

- ▶ New ERI path has a different *scope* from traditional IECC compliance paths
  - Traditional Performance Path excludes equipment efficiency, appliances, lighting
  - ERI Path includes all end uses
  
- ▶ ERI Path, like the traditional Performance Path, is a simulated performance approach
  - But with a different metric for judging equivalence
  - And different rules for performance simulation
  
- ▶ Consequently, questions may arise during adoption
  - Are the paths really equivalent?
  - What if locals disagree with ERI thresholds?

# Background – Why yet another HERS analysis?

- ▶ What's not really new
  - The way HERS Index varies with house size and some other characteristics is well known
  - Our results generally match FSEC's and others'
  
- ▶ What is different
  - Focus on HERS vs IECC (i.e., focus on compliance verdicts rather than energy equivalence of various configurations)
  - Attempt to be more comprehensive, with results in one place
  - Attempt to smooth out results across multiple house configurations (both complying and non-complying)
  - Format such that results are easy to use in adoption processes

# PNNL's HERS Analysis

- ▶ Compares HERS Index with 2012<sup>(\*)</sup> IECC Performance Path
- ▶ Calculates a *Corresponding HERS Index* (CHI), which is the HERS Index that yields a compliance decision comparable to the traditional Performance Path
  - (Same compliance verdict for in-scope elements of the traditional path)
- ▶ Considers a broad range of house features, both within and outside the traditional Performance Path's scope

324 configurations x 15 zones  
x 3 envelope efficiencies x 4 simulations (for ratios and HERS Indexes)

+ 1 configuration x 15 zones x 6 HVAC efficiency packages  
x 3 envelope efficiencies x 4 simulations (for ratios and HERS Indexes)

= 59,400 *EnergyPlus* simulations

\* 2015 base requirements are essentially equivalent to 2012 IECC

# House Characteristics Analyzed

- ▶ Window-floor ratios: 12%, 16%, 25%
- ▶ Conditioned floor area: 1200, 2400, 5000 ft<sup>2</sup>
- ▶ Foundation: slab, vented crawlspace, heated basement
- ▶ No. of stories: 1, 2
- ▶ Orientation: E/W dominant, neutral, N/S dominant
- ▶ Appliances: Standard, ENERGY STAR
- ▶ HVAC Efficiency: Federal minimum plus higher options (3 gas/AC & 2 heat pump options)
- ▶ Climates: one per climate zone-moisture regime
- ▶ Envelope Efficiency: IECC-minimum, lower, higher(\*)

\* Used only in calculating CHI

# House Characteristics Analyzed

- ▶ Window-floor ratios: 12%, 16%, 25%
- ▶ Conditioned floor area: 1200, 2400, 5000 ft<sup>2</sup>
- ▶ Foundation: slab-on-grade, crawlspace, heated basement
- ▶ No. of stories: 1, 1.5, 2
- ▶ Orientation: N, S, E, W
- ▶ Appliances: none, electric, gas
- ▶ HVAC Equipment: none, electric, gas, heat pump, geothermal, solar thermal, solar PV
- ▶ Climates: one per climate zone-moisture regime
- ▶ Envelope Efficiency: IECC-minimum, lower, higher(\*)

Why these?

- Expected to matter
- Potentially useful in ERI thresholds that discriminate by building type or characteristics

\* Used only in calculating CHI

# HERS Analysis – Primary Considerations

## ▶ Magnitude

- Do the 2015 IECC's ERI thresholds consistently ensure reasonable compliance equivalency? (*Yes*)
- Does the new ERI path set up any “free rider” or “path shopping” bypasses? (*No*)

## ▶ Variability

- Because HERS Index and traditional Performance Path are different systems, the calculated CHI varies with house characteristics
- Can generalizations be made to inform potential adoption questions?



# Corresponding HERS Index (CHI)

- ▶ Simply calculating HERS Index for a house with IECC prescriptive minimums may introduce bias or unnecessary variability
  - Prescriptive and traditional Performance paths are not perfectly aligned (i.e., the prescriptive inputs don't necessarily exactly comply via the performance path)
  - Choice of a specific envelope combination (out of multiple that might minimally comply) may bias individual CHIs, introducing “noise” across the range of characteristics analyzed
  
- ▶ Procedure was developed to capture the differential ways HERS Index and traditional Performance Path vary with envelope configuration

# Calculating Corresponding HERS Index (CHI)

- ▶ Define an IECC Compliance Ratio:

$$(E\$_{\text{proposed}} / E\$_{\text{standard reference}})$$

where 1.0 = minimal compliance, <1.0 = better, >1.0 = worse

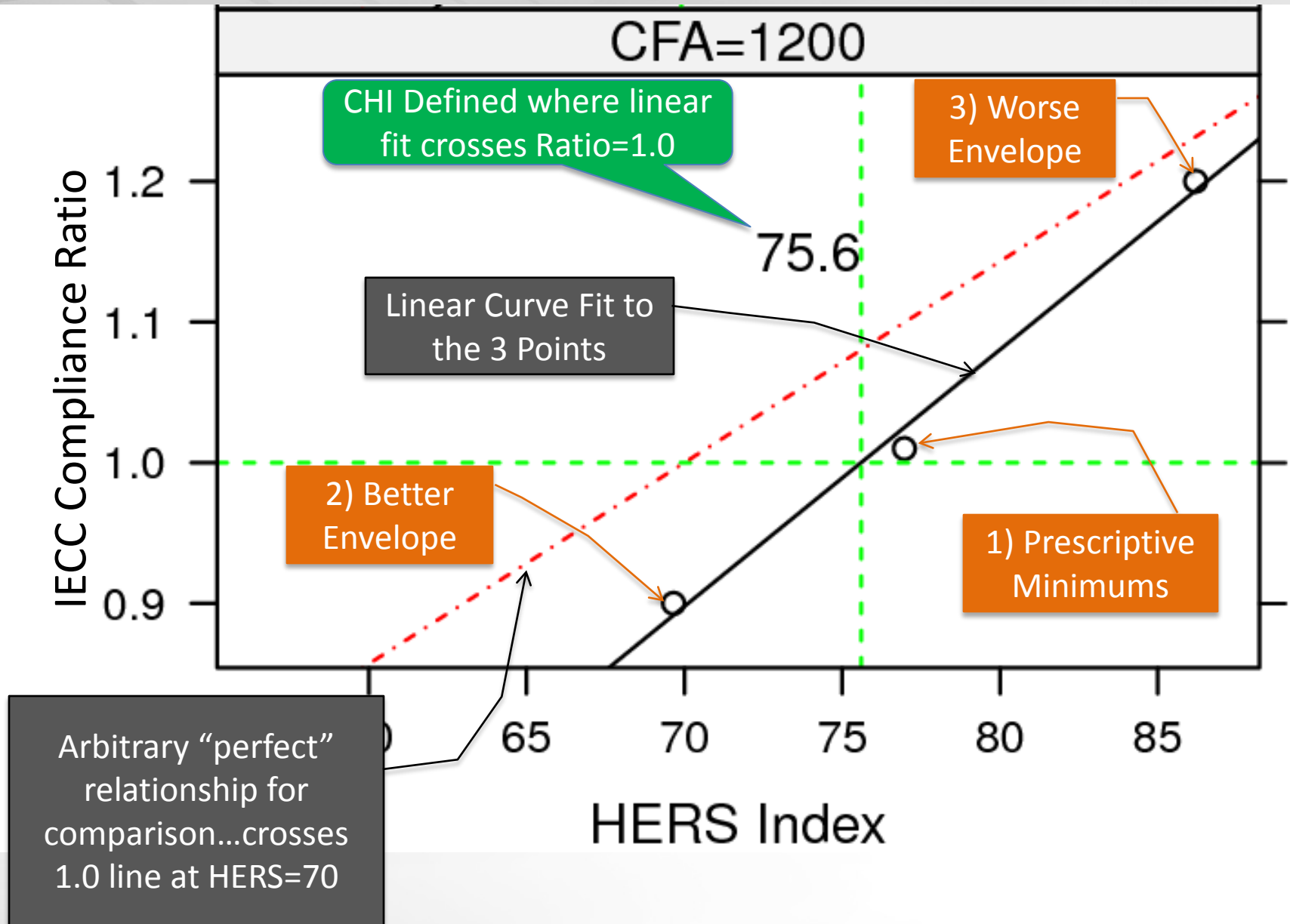
- ▶ For each house configuration, simulate three envelope levels:

1. prescriptive minimum
2. moderately better
3. moderately worse

} Compute both HERS Index and  
IECC Compliance Ratio for all three

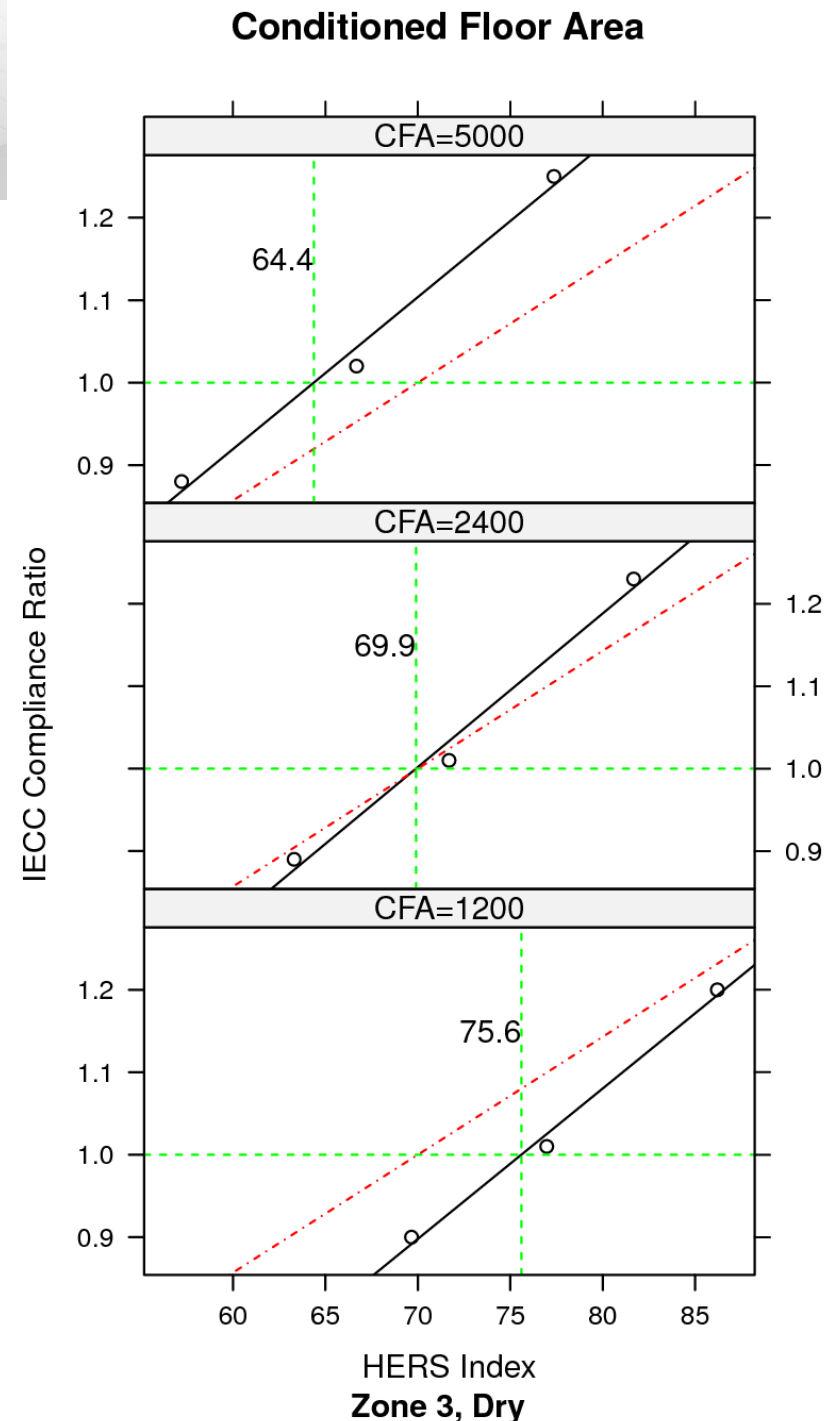
- ▶ Fit a curve (linear) through the three points to characterize how the two metrics track each other
- ▶ Define the CHI as the HERS Index where the curve crosses the Compliance Ratio = 1.0 line

# Calculating Corresponding HERS Index (CHI)



# Example CHI Calculation (Zone 3-Dry)

- ▶ Note how CHI changes with CFA
  - Slope (IECC Compliance Ratio vs HERS Index) is similar regardless of home size
  - Slope differs from “perfect” line as expected; in this case, HERS gives slightly less credit/penalty for envelope changes
  - CHI depends strongly on CFA, but not linearly
    - Doubling CFA (1200 to 2400) gives a delta-CHI of 5.7
    - Doubling again (2400 to 5000) gives a similar delta-CHI of 5.5
- ▶ Details of correlations differ by climate zone and house characteristics  
(Report shows all CHI graphics)



# Calculating *Corresponding HERS Index (CHI)*, cont'd.

- ▶ CHI was calculated for every combination (324) of the house characteristics  
(HVAC efficiency done separately...more on that later)
  
- ▶ Voluminous results were presented in the form of “decision trees” that highlight the most influential house characteristics
  - Allows easy visualization of the most important house characteristics
  - Allows easy reasoning of how multi-level ERI thresholds might be conceived if states/localities need such during adoption processes(More on that in a moment)

# Magnitude: Comparison of CHI with IECC ERI thresholds

Climate Zone	Moisture Regime	Range of CHI Values		2015 IECC ERI Threshold
		With Federal Minimum Equipment Efficiency	With Highest AC and Gas Furnace Efficiencies Analyzed	
1	Moist	57-82	47-72	52
2	Moist	62-83	54-75	52
	Dry	59-80	49-70	
3	Moist	55-77	47-69	51
	Dry	58-77	50-69	
	Marine	56-82	52-78	
4	Moist	56-79	48-71	54
	Dry	56-77	48-69	
	Marine	58-82	54-78	
5	Moist	55-81	47-73	55
	Dry	58-82	53-77	
6	Moist	55-79	48-72	54
	Dry	58-81	51-74	
7	NA	53-77	44-68	53
8	NA	55-78	45-68	53

# Magnitude: Comparison of CHI with IECC ERI thresholds

Climate Zone	Moisture Regime	Range of CHI Values		2015 IECC ERI Threshold
		With Federal Minimum Equipment Efficiency	With Highest AC and Gas Furnace Efficiencies Analyzed	
1	Moist	57-82	47-72	52
			54-75	52
			49-70	
			47-69	51
			50-69	
			52-78	
			48-71	54
			48-69	
			54-78	
			47-73	
			53-77	55
			48-72	
			51-74	54
7	NA	53-77	44-68	53
8	NA	55-78	45-68	53

CHI values are usually higher than the IECC's ERI thresholds, meaning:

- ERI path is generally conservative (more efficient more often than less efficient relative to traditional Performance Path)
- Only when the higher analyzed equipment efficiencies are used in calculating an ERI would the new path comply a home that would be rejected by the traditional path; and even then, only for some house configurations

# Variability: How CHI varies with house characteristics

- ▶ Challenge: present 324 CHI results per climate zone in a useful way
- ▶ Solution: decision trees based on a recursive partitioning analysis scheme
  - Recursive partitioning attempts to classify the results based on dichotomous splitting of independent variables (the house characteristics)
  - I.O.W., it identifies the most important characteristic in determining the CHI, then...
    - Given each specified level of that characteristic, identifies the next most important characteristic, then...
      - ◆ Given each specified level of that characteristic, identifies the next most important characteristic, then...
        - ▶ Given each specified level...etc.
  - Easier to show an example...



# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For				Corresponding HERS Index Range	
				Min.	Max.
None	CFA = 2400 or 5000	CFA = 5000		56	64
		CFA = 2400	ENERGY STAR Appliances	63	68
			Standard Appliances	66	71
	CFA = 1200	ENERGY STAR Appliances		70	74
		Standard Appliances		75	79

(Assumes federal minimum equipment efficiencies)

# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For			Corresponding HERS Index Range		
			Min.	Max.	
None	CFA = 2400 or 5000	CFA = 5000	56	64	
		With no differentiation by house features, the range of Corresponding HERS Index values is 56 to 79 (a span of 23 points) in this zone/regime.	R	63	68
				66	71
	CFA = 1200	ENERGY STAR Appliances	70	74	
		Standard Appliances	75	79	

(Assumes federal minimum equipment efficiencies)

# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For			Corresponding HERS Index Range		
			Min.	Max.	
None	CFA = 2400 or 5000	CFA = 5000	56	64	
		CFA	Differentiating by house size narrows the range.	63	68
			Taking <u>small homes</u> in isolation, the range is only 70 to 79 (span of 9 points)	66	71
	CFA = 1200	ENERGY STAR Appliances	70	74	
		Standard Appliances	75	79	

(Assumes federal minimum equipment efficiencies)

# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For			Corresponding HERS Index Range		
			Min.	Max.	
None	CFA = 2400 or 5000	CFA = 5000	56	64	
		CFA	Among <u>small homes with standard appliances</u> , the range is only 75 to 79 (span of 4 points)	63	68
			Appliances	66	71
	CFA = 1200	ENERGY STAR Appliances	70	74	
		Standard Appliances	75	79	

(Assumes federal minimum equipment efficiencies)

# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For				Corresponding HERS Index Range	
				Min.	Max.
None	CFA = 2400 or 5000	CFA = 5000		56	64
		CFA = 2400	ENERGY STAR Appliances	63	68
			Standard Appliances	66	71
	CFA = 1200	ENERGY STAR Appliances		Among <u>average size homes</u> , the range is 63 to 71 (span of 8 points)	
		Standard Appliances			

(Assumes federal minimum equipment efficiencies)

# Variability: How CHI varies with house characteristics

## Example results for Zone 4-Moist

Characteristics Accounted For				Corresponding HERS Index Range	
				Min.	Max.
None	CFA = 2400 or 5000	CFA = 5000		56	64
		CFA = 2400	ENERGY STAR Appliances	63	68
			Standard Appliances	66	71
	CFA = 1200	ENERGY STAR Appliances		Among <u>average size homes with ENERGY STAR appliances</u> , the range is 63 to 68 (span of 5 points)	
		Standard Appliances			

(Assumes federal minimum equipment efficiencies)

# Summary of Most Important Characteristics

- ▶ In virtually every climate zone, three characteristics stand out as most important in explaining CHI variability
  - House size (always once, sometimes twice; small usually more significant than large)
  - Appliance efficiency
  - HVAC efficiency (not yet discussed)
  
- ▶ In a few zones, additional characteristics show up as secondarily important
  - Foundation type
  - Window-floor ratio
  - No. of stories
  
- ▶ Additional characteristics help, but probably introduce excessive complexity for code purposes



## Variability: How CHI varies with house characteristics and HVAC efficiencies

- ▶ There is one decision tree for each combination of climate zone and moisture regime
- ▶ HVAC efficiency level is handled separately by simulating each efficiency level only at the middle values of other house characteristics
  - Gives a fixed offset to be subtracted from the federal-minimum CHI values



# Decision Tree Example with Other HVAC Efficiency Levels

## Example results for Zone 4-Moist

Characteristics Accounted For				Corresponding HERS Index Range <sup>(*)</sup>	
				Min.	Max.
None	CFA = 2400 or 5000	CFA = 5000		56/55/50/48	64/63/58/56
		CFA = 2400	ENERGY STAR Appliances	63/62/57/55	68/67/62/60
			Standard Appliances	66/65/60/58	71/70/65/63
	CFA = 1200	ENERGY STAR Appliances		70/69/64/62	74/73/68/66
		Standard Appliances		75/74/69/67	79/78/73/71

\* The 4 numbers represent 4 HVAC efficiency scenarios:

AFUE-78, SEER-13 / AFUE-80, SEER-14 / AFUE-94, SEER-16 / AFUE-96, SEER-20  
 (0) / (-1) / (-6) / (-8)

# Concluding Remarks

- ▶ The correlation between HERS Index and traditional IECC Performance Path is complex and the differences are significant
  - A single HERS (or ERI) threshold per zone cannot adequately ensure compliance equivalence between paths
  - The 2015 IECC's ERI thresholds address this by being conservative—they are low enough to ensure that most homes will be equal to or better than those complying by the traditional path and there are few opportunities for path shopping or free-riders
  - But for many house configurations, a higher threshold might be reasonable, especially if there were an optional path restricted to federal-minimum equipment efficiency
  
- ▶ By examining the decision trees for a given climate zone, a state or local jurisdiction can make decisions
  - Whether a multi-level ERI threshold would be helpful
  - If so, what house characteristics should be used to discriminate the levels

# Acknowledgements and Links

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- ▶ The complete analysis can be obtained at:  
[http://www.energycodes.gov/development/residential/iecc\\_analysis](http://www.energycodes.gov/development/residential/iecc_analysis)