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Aligning HERS Indices for State Code Adoption

Consistency among states adopting ERI compliance paths

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Overview

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- DOE's Economic Analysis Methodology
  (with emphasis on prototype building models)
- PNNL's HERS Analysis
  (identifying the most significant building characteristics affecting compliance verdicts)
- Discussion: application, the case for consistency, etc.

Overview of DOE's Economic Analysis Methodology – Three Primary Elements

1. Standard building prototypes and modeling assumptions
2. Aggregation scheme
3. Economic metrics and assumptions

Elements of DOE's Economic Analysis Methodology

- Standard building prototypes and corresponding *EnergyPlus* models
  - 2 building types

    (single-family and low-rise multifamily)
  - 4 foundation types

    (slab, crawlspace, heated and unheated basement)
  - 4 HVAC fuel/system types

    (Gas, Elec, or Oil furnace with A/C; Heat Pump)
  - Predefined sizes and configurations

    …but with ability to modify for parametric analyses (size, aspect ratio, number of stories, glazing area, efficiency levels, etc.)

Available by state for several IECC codes at:
https://www.energycodes.gov/development/residential/iecc_models

Prototype Characteristics

- Configuration & operation assumptions chosen to approximate average or typical construction

  …appropriate for aggregate analysis

- Simulation assumptions taken from vetted industry sources
  1. IECC (where applicable)
     - Prescriptive requirements
     - Performance path ruleset

     } Code consistency
  2. Building America simulation protocols

     } New construction focus and DOE self-consistency
  3. RESNET specifications
  4. CA Title 24
  5. Etc.

     } Industry consistency

Single-Family Prototype

A simple, rectangular house with predefined (but variable) size, aspect ratio, number of stories, glazing fraction, foundation type, lighting types, internal gains, equipment types, etc.

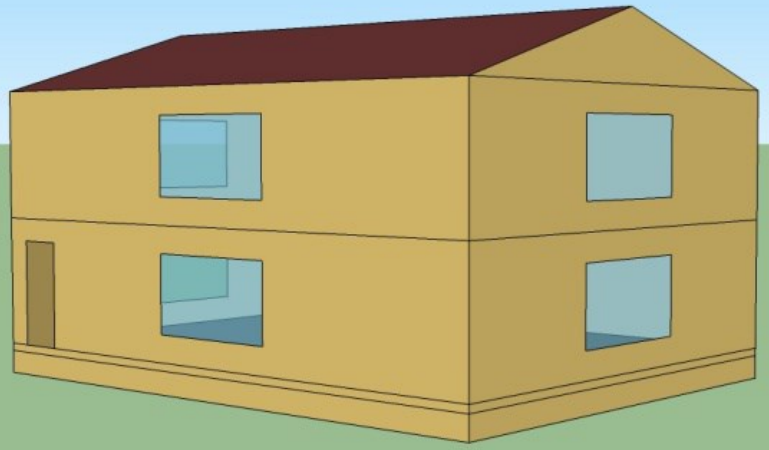


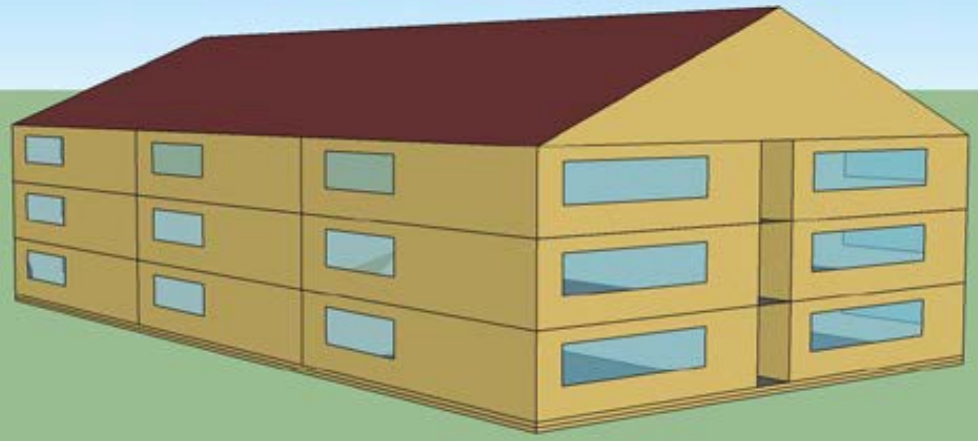
Table 2.1. Single-Family Prototype Characteristics

Parameter	Assumption	Notes
Conditioned floor area	[redacted]	Characteristics of New Housing, U.S. Census Bureau
Footprint and height	[redacted]	
Area above unconditioned space	1,188 ft^2	Over a vented crawlspace or unconditioned basement
Area below roof/ceilings	1,188 ft^2	Under a conditioned attic unless specific roof/ceiling measures warrant other (or multiple) roof/ceiling types
Perimeter length	152 ft	
Gross exterior wall area	2,584 ft^2	
Window area (relative to conditioned floor area)	[redacted]	
Door area	42 ft^2	
Internal gains	[redacted]	2015 IECC, Table R405.5.2(1), assuming three bedrooms. May vary if homes of different size than the standard prototype are analyzed.
Heating system	Natural gas furnace, heat pump, electric furnace, or oil-fired furnace	Efficiencies will be based on prevailing federal minimum manufacturing standards.
Cooling system	Central electric air conditioning	Efficiency will be based on prevailing federal minimum manufacturing standards.
Water heating	Same as fuel used for space heating, or as required to evaluate domestic hot water-specific code changes	

Btu = British thermal units.
IECC = International Energy Conservation Code.

Low-Rise Multifamily Prototype

A simple, rectangular, 3-story apartment building with six apartments per floor, a middle breezeway, predefined (but variable) size, aspect ratio, etc.



DOE's Residential Prototypes – Summary

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- Designed to approximate average construction
- Designed to be appropriate for aggregate analysis
- Designed to derive assumptions from other industry sources

Elements of DOE's Economic Analysis Methodology (FYI only)

- Aggregation scheme and corresponding weighting factors based on housing starts split by 8 factors

1. State
2. Climate Zone
3. Moisture Regime
4. Humidity Designation
5. Tropical Designation
6. Building Type
7. Foundation Type
8. HVAC Fuel/System Type

Aggregated results available within/across any of the factors

Elements of DOE's Economic Analysis Methodology (FYI only)

- Standard economic analysis methodology that represents all owners of a home
  - Life-Cycle Cost (LCC) is DOE's primary metric
    - 30-year analysis period with 30-year fixed-rate mortgage
    - Assumes life-for-like replacement of components at end of life
    - Assumes pro-rated residual values (resale premium) at end of analysis period
  - Simple Payback Period and Cash Flow Analysis also reported

How much does it matter?

PNNL's HERS Analysis

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Z Todd Taylor and Vrushali Mendon, May 2014. *Identification of RESNET HERS Index Values Corresponding to Minimal Compliance with the IECC Performance Path*. Pacific Northwest National Laboratory. PNNL-22560.

Available at: https://www.energycodes.gov/development/residential/iecc_analysis

- Sought to characterize how the RESNET HERS Index relates to the traditional performance path
- Evaluated a broad range of single-family house configurations
  - 3 sizes, 3 glazing ratios, 4 foundations, 1&2 stories, 2 orientations, 2 appliance eff levels, 15 climates)
  - Plus 5 HVAC type/efficiency combos
  - Total of 324 configurations per climate

PNNL's HERS Analysis, cont'd.

- For each of the 324 configurations:
  - Simulated 3 efficiency levels
    - Code minimum (prescriptive path)
    - Moderately more efficient
    - Moderately less efficient
  - Calculated 2 metrics
    - HERS Index
    - IECC Compliance Ratio ($E\$_{proposed}/E\$_{stdref}$)
  - Determined 1 final descriptor: Corresponding HERS Index (CHI)

    Defined as the HERS Index that yields the <u>same compliance verdict</u> as the traditional performance path (for in-scope elements of the latter)

To smooth out bias due to prescriptive/performance path differences

Defined to facilitate comparisons (not part of IECC specifications)

PNNL's HERS Analysis, cont'd.

- Results generally support the 2015 IECC's ERI thresholds
  Very few house configurations complying via ERI would fail via the traditional performance path
- Results show substantial variation as a function of several key building characteristics
  Generally similar to what others have found with regard to conditioned floor area
- Results allow ordering of building characteristics by importance in affecting consistency of compliance verdicts between ERI and traditional performance path

PNNL's HERS Analysis, cont'd.

- Report presents the voluminous CHI results in the form of *decision trees*
  - Based on a recursive partitioning statistical technique
  - Show the most important characteristic in minimizing the range of CHI
    - Then the next most important characteristic
      - Then the next most important characteristic
        - Etc.
  - Easier to show an example…

Variability: How CHI varies with house characteristics

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Example results for Zone 4-Moist (324 configurations)

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)

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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.

(Assumes federal minimum equipment efficiencies)

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	CFA = 1200	ENER		70	74
		Stand		75	79

(Assumes federal minimum equ

Differentiating by house size narrows the range.

Taking med & large homes in isolation, the range is only 56 to 71 (span of 15 points)

Variability: How CHI varies with house characteristics

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		Standard Appliances		75	79

Taking small homes in isolation, the range is only 70 to 79 (span of 9 points)

(Assumes federal minimum equipment efficiencies)

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		CFA		63	68
			Appliances	66	71
	CFA = 1200	ENERGY STAR Appliances		70	74
		Standard Appliances		75	79

Among small homes with standard appliances, the range is only 75 to 79 (span of 4 points)

(Assumes federal minimum equipment efficiencies)

Variability: How CHI varies with house characteristics

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(Assumes federal minimum equipment efficiencies)

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Variability: How CHI varies with house characteristics

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		Standard Appliances		75	79

(Assumes federal minimum equipment efficiencies)

Decision Tree Example with Other HVAC Efficiency Levels

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Characteristics Accounted For				Corresponding HERS Index Range(*)	
				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)

Discussion