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Creating Energy Independence

Analysis of HERS Index Scores for Recent Versions of the International Energy Conservation Code (IECC)

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Background

The Residential Energy Services Network (RESNET) contracted the Florida Solar Energy Center (FSEC) to conduct simulation analysis of homes configured to recent versions of the International Energy Conservation Code (IECC) to determine HERS Index Scores for typical residences across representative U.S. climates. EnergyGauge® USA (v.2.8.05), a RESNET-accredited HERS software tool, was used to conduct the simulation analysis.

The original study was published January 11, 2013, and three days later, on January 14, 2013, the U.S. Department of Energy (DOE) vacated its Final Rule on gas furnace efficiency. Vacation of the gas furnace efficiency Rule caused the energy estimates based on that rule to be inaccurate. The analysis has been revised to include an additional set of simulations and analysis that excludes the furnace efficiencies previously scheduled to become effective May 2013. The results and findings have been revised accordingly.

Abstract

The EnergyGauge HERS software tool was used to examine the IECC *Standard Reference Design* (IECC SRD) configuration for one-story 2000 ft^2 and two-story 2,400 ft^2 single-family homes in sixteen representative U.S. cities. IECC SRD homes were configured for the 2006 IECC, the 2009 IECC and the 2012 IECC. Two additional set of analysis were conducted – both using the 2012 IECC SRD with enhanced equipment: 1) with equipment configured to meet the 2015 National Appliance Energy Conservation Act (NAECA) equipment requirements and 2) with equipment that is on the cusp of significant market penetration with efficiencies greater than the 2015 standard.

HERS simulations for each home were conducted for both a *best case* home orientation and a *worst case* home orientation. For the overall *best-case* configuration (2-story home with north-south glazing orientation), results show a nationwide, climate-weighted average increase in code stringency of 13.6% between 2006 and 2009, a 19.1% increase between 2006 and 2012 and a 21.5% increase between 2006 and 2012 with 2015 NAECA equipment. Incorporating higher efficiency equipment on the cusp of significantly broader market adoption due to federal initiatives[1] resulted in a nationwide climate-weighted average 35.2% savings with respect to the 2006 IECC.

[1] For example, see U.S. DOE Challenge Home guidelines and http://www.energystar.gov/index.cfm?c=new_homes.hm_index

Methodology

One-story, 2000 ft^2, 3-bedroom frame homes and two-story, 2400 ft^2, 3-bedroom frame homes were configured to simulate the IECC *Standard Reference Design* in sixteen representative cities across the eight IECC climate regions of the United States. Windows were configured such that 35% of the total window area was located on the north and south faces of the home and 15% was located on the east and west faces. This allowed the simulations to examine a *best-case* orientation scenario with the front of the homes facing north and a *worst-case* scenario with the front facing east. The front of the homes also had a 20-foot adjoining garage wall. The foundation for the homes was varied by IECC climate zone with slab-on-grade foundations in zones 1 and 2, vented crawlspace foundations in zones 3 and 4 and with unconditioned basement foundations in zones 5 through 8.

Tables 1 through 8 present the characteristics for the 224 different home configurations used in the simulation analysis.

Table 1: *Best-Case* Home Characteristics

Component	1-story	2-Story
1st floor area (ft^2)	2,000	1,200
2nd floor area (ft^2)	0	1,200
Total floor area (ft^2)	2,000	2,400
Total volume (ft^3)	18,000	21,000
N-S wall length (ft)	50	40
E-W wall length (ft)	40	30
1st floor wall height (ft)	9	8
Height between floors (ft)	0	1.5
2nd floor wall height (ft)	0	8
Door area ft^2)	40	40
2006 IECC SRD windows:		
Window/floor area (%)	18%	18%
Total window area (ft^2)	360	432
N-S window fraction (%)	35%	35%
E-W window fraction (%)	15%	15%
2009 - 2012 IECC SRD windows:		
Window/floor area (%)	15%	15%
Total window area (ft^2)	300	360
N-S window fraction (%)	35%	35%
E-W window fraction (%)	15%	15%

Table 2: 2006 IECC Component Insulation Values

LOCATION	IECC CZ	Ceiling R-value	Wall R-value	Found. type	Slab R-value	Floor R-value	Fen U-Factor	Fen SHGC
Miami, FL	1A	30	13	SOG	none	n/a	1.20	0.40
Orlando, FL	2A	30	13	SOG	none	n/a	0.75	0.40
Houston, TX	2A	30	13	SOG	none	n/a	0.75	0.40
Phoenix, AZ	2B	30	13	SOG	none	n/a	0.75	0.40
Charleston, SC	3A	30	13	Crawl	n/a	19	0.65	0.40
Charlotte, NC	3A	30	13	Crawl	n/a	19	0.65	0.40
Ok. City, OK	3A	30	13	Crawl	n/a	19	0.65	0.40
Las Vegas, NV	3B	30	13	Crawl	n/a	19	0.65	0.40
Baltimore, MD	4A	38	13	Crawl	n/a	19	0.40	0.40
Kansas City, MO	4A	38	13	Crawl	n/a	19	0.40	0.40

Table 2: 2006 IECC Component Insulation Values

LOCATION	**IECC CZ**	Ceiling R-value	Wall R-value	Found. type	Slab R-value	Floor R-value	Fen U-Factor	Fen SHGC
Chicago, IL	5A	38	13+5	UCbsmt	n/a	30	0.35	0.40
Denver, CO	5B	38	13+5	UCbsmt	n/a	30	0.35	0.40
Minneapolis, MN	6A	49	13+5	UCbsmt	n/a	30	0.35	0.40
Billings, MT	6B	49	13+5	UCbsmt	n/a	30	0.35	0.40
Fargo, ND	7A	49	21	UCbsmt	n/a	30	0.35	0.40
Fairbanks, AK	8	49	21	UCbsmt	n/a	30	0.35	0.40

Notes for Tables 2-4:

Wall R-value: 1st value is cavity fill and 2nd value is continuous insulation
SOG = slab on grade
Crawl = crawlspace
UCbsmt = unconditioned basement

Table 3: 2009 IECC Component Insulation Values

LOCATION	**IECC CZ**	Ceiling R-value	Wall R-value	Found. type	Slab R-value	Floor R-value	Fen U-Factor	Fen SHGC
Miami, FL	1A	30	13	SOG	none	n/a	1.20	0.30
Orlando, FL	2A	30	13	SOG	none	n/a	0.65	0.30
Houston, TX	2A	30	13	SOG	none	n/a	0.65	0.30
Phoenix, AZ	2B	30	13	SOG	none	n/a	0.65	0.30
Charleston, SC	3A	30	13	Crawl	n/a	19	0.50	0.30
Charlotte, NC	3A	30	13	Crawl	n/a	19	0.50	0.30
Ok. City, OK	3A	30	13	Crawl	n/a	19	0.50	0.30
Las Vegas, NV	3B	30	13	Crawl	n/a	19	0.50	0.30
Baltimore, MD	4A	38	13	Crawl	n/a	19	0.35	0.40
Kansas City, MO	4A	38	13	Crawl	n/a	19	0.35	0.40
Chicago, IL	5A	38	13+5	UCbsmt	n/a	30	0.35	0.40
Denver, CO	5B	38	13+5	UCbsmt	n/a	30	0.35	0.40
Minneapolis, MN	6A	49	13+5	UCbsmt	n/a	30	0.35	0.40
Billings, MT	6B	49	13+5	UCbsmt	n/a	30	0.35	0.40
Fargo, ND	7A	49	21	UCbsmt	n/a	38	0.35	0.40
Fairbanks, AK	8	49	21	UCbsmt	n/a	38	0.35	0.40

Table 4: 2012 IECC Component Insulation Values

LOCATION	**IECC CZ**	Ceiling R-value	Wall R-value	Found. type	Slab R-value	Floor R-value	Fen U-Factor	Fen SHGC
Miami, FL	1A	30	13	SOG	none	n/a	0.50	0.25
Orlando, FL	2A	38	13	SOG	none	n/a	0.40	0.25
Houston, TX	2A	38	13	SOG	none	n/a	0.40	0.25
Phoenix, AZ	2B	38	13	SOG	none	n/a	0.40	0.25
Charleston, SC	3A	38	13+5	Crawl	n/a	19	0.35	0.25
Charlotte, NC	3A	38	13+5	Crawl	n/a	19	0.35	0.25
Ok. City, OK	3A	38	13+5	Crawl	n/a	19	0.35	0.25
Las Vegas, NV	3B	38	13+5	Crawl	n/a	19	0.35	0.25
Baltimore, MD	4A	49	13+5	Crawl	n/a	19	0.35	0.40
Kansas City, MO	4A	49	13+5	Crawl	n/a	19	0.35	0.40
Chicago, IL	5A	49	13+5	UCbsmt	n/a	30	0.32	0.40
Denver, CO	5B	49	13+5	UCbsmt	n/a	30	0.32	0.40
Minneapolis, MN	6A	49	13+10	UCbsmt	n/a	30	0.32	0.40
Billings, MT	6B	49	13+10	UCbsmt	n/a	30	0.32	0.40
Fargo, ND	7A	49	13+10	UCbsmt	n/a	38	0.32	0.40
Fairbanks, AK	8	49	13+10	UCbsmt	n/a	38	0.32	0.40

Table 5: Additional IECC *Standard Reference Design* Characteristics

Item	**2006 IECC**	**2009 IECC**	**2012 IECC**
Envelope Leakage	SLA = 0.00036	7 ach50	CZ 1-2: 5 ach50 CZ 3-8: 3 ach50
Distribution System Efficiency (DSE)	DSE = 0.80	DSE = 0.88	DSE = 0.88
Programmable Thermostat	No	Yes	Yes
High Efficiency Lighting	No	50%	75%
Hot Water Pipe Insulation	No	No	Yes
Max Window/Floor area	18%	15%	15%
Mechanical Ventilation (per 2012 IMC)	None	None	CZ 1-2: None CZ 3-8: 60 cfm
Sealed Air Handlers	No	No	Yes

Base thermostat setpoint temperatures for all simulations were maintained at the IECC 2006 values of 78F for cooling and 68F for heating. While the 2009 IECC and 2012 IECC use 75 F for cooling and 72 F for heating, use of these base thermostat setpoints for 2009 and 2012 IECC simulations would not allow comparison across code versions.

Table 6: Current Equipment Standards

LOCATION	**IECC CZ**	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	7.7	elec	13	elec (50)	0.90
Orlando, FL	2A	elec	7.7	elec	13	elec (50)	0.90
Houston, TX	2A	elec	7.7	elec	13	elec (50)	0.90
Phoenix, AZ	2B	elec	7.7	elec	13	elec (50)	0.90
Charleston, SC	3A	elec	7.7	elec	13	elec (50)	0.90
Charlotte, NC	3A	gas	78%	elec	13	gas (40)	0.59
Ok. City, OK	3A	gas	78%	elec	13	gas (40)	0.59
Las Vegas, NV	3B	gas	78%	elec	13	gas (40)	0.59
Baltimore, MD	4A	gas	78%	elec	13	gas (40)	0.59
Kansas City, MO	4A	gas	78%	elec	13	gas (40)	0.59
Chicago, IL	5A	gas	78%	elec	13	gas (40)	0.59
Denver, CO	5B	gas	78%	elec	13	gas (40)	0.59
Minneapolis, MN	6A	gas	78%	elec	13	gas (40)	0.59
Billings, MT	6B	gas	78%	elec	13	gas (40)	0.59
Fargo, ND	7A	gas	78%	elec	13	gas (40)	0.59
Fairbanks, AK	8	gas	78%	elec	13	gas (40)	0.59

Notes for Tables 6 through 8:

Eff = heating system efficiency where gas-fired furnace is given as AFUE (%) and electric heat pump is given as HSPF

HPWH = Heat pump water heater

T'less gas = Tankless gas water heater

Table 7a: New NAECA Equipment Standards
(with original gas furnace Rule)

LOCATION	**IECC CZ**	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	8.2	elec	14	elec (50)	0.95
Orlando, FL	2A	elec	8.2	elec	14	elec (50)	0.95
Houston, TX	2A	elec	8.2	elec	14	elec (50)	0.95
Phoenix, AZ	2B	elec	8.2	elec	14	elec (50)	0.95

Table 7a: New NAECA Equipment Standards
(with original gas furnace Rule)

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Charleston, SC	3A	elec	8.2	elec	14	elec (50)	0.95
Charlotte, NC	3A	gas	80%	elec	14	gas (40)	0.62
Ok. City, OK	3A	gas	80%	elec	14	gas (40)	0.62
Las Vegas, NV	3B	gas	80%	elec	14	gas (40)	0.62
Baltimore, MD	4A	gas	80%	elec	14	gas (40)	0.62
Kansas City, MO	4A	gas	90%	elec	13	gas (40)	0.62
Chicago, IL	5A	gas	90%	elec	13	gas (40)	0.62
Denver, CO	5B	gas	90%	elec	13	gas (40)	0.62
Minneapolis, MN	6A	gas	90%	elec	13	gas (40)	0.62
Billings, MT	6B	gas	90%	elec	13	gas (40)	0.62
Fargo, ND	7A	gas	90%	elec	13	gas (40)	0.62
Fairbanks, AK	8	gas	90%	elec	13	gas (40)	0.62

Table 7b: New NAECA Equipment Standards
(with gas furnace Rule vacated)

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	8.2	elec	14	elec (50)	0.95
Orlando, FL	2A	elec	8.2	elec	14	elec (50)	0.95
Houston, TX	2A	elec	8.2	elec	14	elec (50)	0.95
Phoenix, AZ	2B	elec	8.2	elec	14	elec (50)	0.95
Charleston, SC	3A	elec	8.2	elec	14	elec (50)	0.95
Charlotte, NC	3A	gas	78%	elec	14	gas (40)	0.62
Ok. City, OK	3A	gas	78%	elec	14	gas (40)	0.62
Las Vegas, NV	3B	gas	78%	elec	14	gas (40)	0.62
Baltimore, MD	4A	gas	78%	elec	14	gas (40)	0.62
Kansas City, MO	4A	gas	78%	elec	13	gas (40)	0.62
Chicago, IL	5A	gas	78%	elec	13	gas (40)	0.62
Denver, CO	5B	gas	78%	elec	13	gas (40)	0.62
Minneapolis, MN	6A	gas	78%	elec	13	gas (40)	0.62
Billings, MT	6B	gas	78%	elec	13	gas (40)	0.62
Fargo, ND	7A	gas	78%	elec	13	gas (40)	0.62
Fairbanks, AK	8	gas	78%	elec	13	gas (40)	0.62

The original natural gas furnace component of the new NAECA standards (Table 7a) was originally scheduled to become effective May 1, 2013. However, the original gas furnace Rule was vacated by DOE on January 14, 2013. Table 7b shows the result of vacating this gas furnace Rule. The air conditioning and heat pump components become effective January 1, 2015, and the water heating component becomes effective April 15, 2015. These components of the 2015 NAECA standards do not change between Tables 7a and Table 7b.

Note also that results and findings based on Tables 7a and Table 7b are differentiated as ‘eq2015’ for the original 2015 equipment standards with the gas furnace Rule in place and as ‘eq2015r’ for the revised equipment standards with the gas furnace Rule vacated.

Table 8: Equipment on the Cusp of Significant Market Adoption

LOCATION	IECC CZ	Heating System		Cooling System		Water Heater	
		Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	elec	8.6	elec	16	HPWH	2.00
Orlando, FL	2A	elec	8.6	elec	16	HPWH	2.00
Houston, TX	2A	elec	8.6	elec	16	HPWH	2.00
Phoenix, AZ	2B	elec	8.6	elec	16	HPWH	2.00
Charleston, SC	3A	elec	8.6	elec	16	HPWH	2.00
Charlotte, NC	3A	gas	90%	elec	16	T'less Gas	0.82
Ok. City, OK	3A	gas	90%	elec	16	T'less Gas	0.82
Las Vegas, NV	3B	gas	90%	elec	16	T'less Gas	0.82
Baltimore, MD	4A	gas	90%	elec	16	T'less Gas	0.82
Kansas City, MO	4A	gas	95%	elec	16	T'less Gas	0.82
Chicago, IL	5A	gas	95%	elec	16	T'less Gas	0.82
Denver, CO	5B	gas	95%	elec	16	T'less Gas	0.82
Minneapolis, MN	6A	gas	95%	elec	16	T'less Gas	0.82
Billings, MT	6B	gas	95%	elec	16	T'less Gas	0.82
Fargo, ND	7A	gas	95%	elec	16	T'less Gas	0.82
Fairbanks, AK	8	gas	95%	elec	16	T'less Gas	0.82

All simulations were accomplished using EnergyGauge USA (v.2.8.05), which is a RESNET-accredited HERS Simulation Tool based on hourly DOE-2 simulations.

Findings

<u>HERS Index Scores</u>

Results from the analysis show a steady increase in IECC stringency between 2006 and 2012, with an additional increase resulting from the new NAECA equipment standards in climate zones 1-4 but with no increase in stringency for climate zones 5-8 due to DOE's vacation of the gas furnace Rule. Figure 1presents the climate zone average HERS Index scores for the overall *best-case* for each set of simulations conducted in the analysis, including the differences between the original gas furnace Rule (Figure 1a) and the vacated gas furnace Rule (Figure 1b).

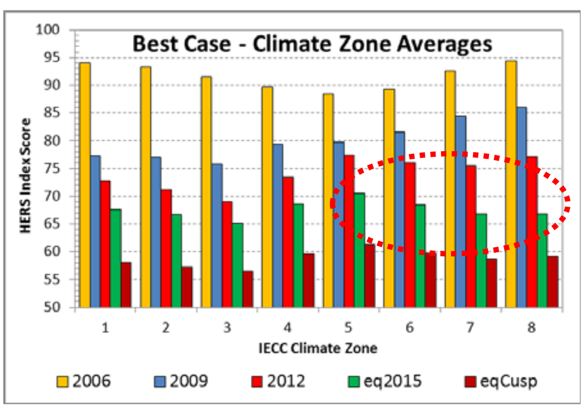

Figure 1a. HERS Index scores for options with original gas furnace Rule.

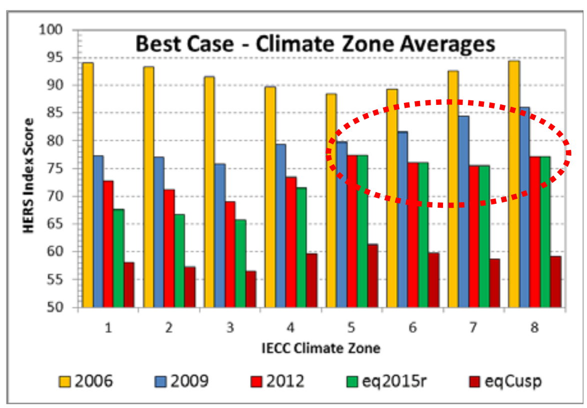

Figure 1b. HERS Index scores for options with vacated gas furnace Rule.

The difference in HERS Index scores between Figure 1a and Figure 1b for the 2015 equipment standards clearly illustrates the reduction in energy savings (increase in HERS Index) in climate zones 5-8 resulting from vacating the gas furnace Rule.

The 2006 HERS Index scores shown in Figure 1 are lower than the HERS Reference Home Index of 100 for three reasons:

1) The simulated homes had *best-case* window orientation with the majority of windows on the north and south face with 16” roof overhangs, reducing both winter and summer energy uses compared with the reference home, which has equal window areas on all sides and no roof overhangs.
2) The infiltration for the HERS Reference Home is based on an SLA of 0.00048 while the 2006 IECC reference has a smaller SLA of 0.00036, making the 2006 IECC more efficient in terms of infiltration loads than the HERS Reference home.
3) The combination of the R-Value ceiling insulation specification with the attic configuration of the homes results in a slightly lower overall U-Factor for the ceiling-attic combination than the U-Factor specified for the IECC SRD and the HERS Reference home.

In all cases, the *best-case* results in Figure 1 are for the two-story homes. The two-story homes produced HERS Index scores that averaged 2 points lower than the one-story homes. This occurred for two reasons:

1) Because the ratio of ceiling area to wall area for the one-story homes is about twice the ratio for the two-story homes
2) The IECC *Standard Reference Design* wall and ceiling insulation requirements are quite different for ceiling and walls, with ceilings having almost twice the thermal insulation resistance of walls.

As a result of these two factors, the IECC *Standard Reference Design* energy use for heating and cooling is larger in the two-story homes than in the one-story homes. The HERS Index score is calculated by dividing the Rated Home’s energy loads by the energy loads of the Reference Home. Since the reference heating and cooling loads are larger for the two-story IECC *Standard Reference Design* than for the one-story *Standard Reference Design*, the larger denominator tends to reduce the HERS Index score in the two-story homes as compared with the one-story homes.

Figure 2 shows the climate zone average HERS Index score results for the 2006 IECC SRD homes. Results are shown for both one-story and two-story home models configured in both their *worst-case* (WC) and *best-case* (BC) configurations. With the exception of the one-story *best-case* home in climate zone 7, the two-story home configuration consistently produces the overall best (lowest) climate zone average HERS Index score.

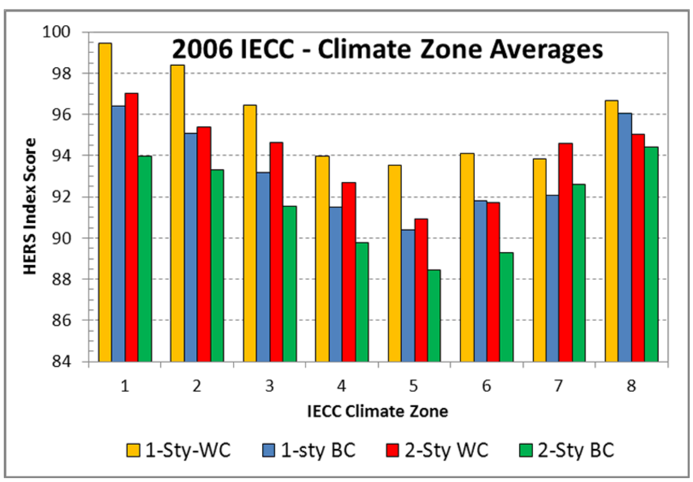

Figure 2. HERS Index scores for the 2006 IECC for 1-story and 2-story *worst-case* and *best-case* home models.

Figure 3 shows the climate zone average HERS Index score results for the 2009 IECC SRD. Again, the better relative performance of the two-story *best-case* home configuration is noticeable. It is also noteworthy that, compared with the 2006 IECC, the HERS Index scores have been reduced much more for homes in southern climate zones than for homes in northern climate zones. Average *best-case* HERS Index scores in climate zones 1-3 were reduced by 17.4% while *best-case* HERS Index scores in climate zones 6-8 were reduced by only 8.8% – roughly half as much.

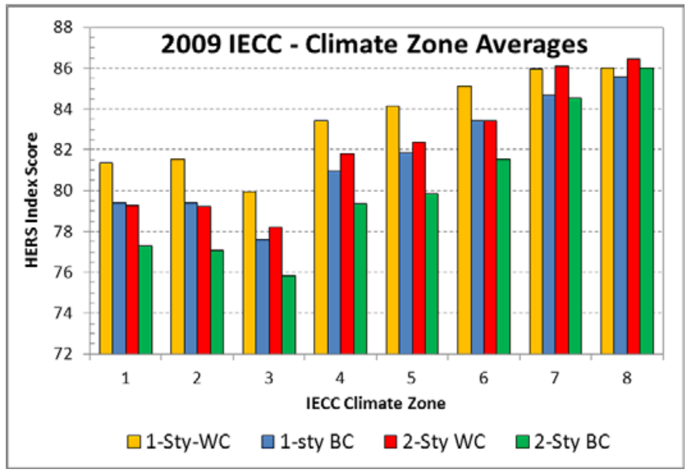

Figure 3. HERS Index scores for the 2009 IECC for 1-story and 2-story *worst-case* and *best-case* home models.

Figure 4 shows the same data for the 2012 IECC SRD. While it is not necessarily clear from the graph, a comparison of the stringency changes in the 2012 IECC SRD with respect to the 2009 IECC SRD show that the climate zone changes are more balanced between north and south than for the 2009 IECC SRD. Average *best-case* HERS Index scores in climate zones 1-3 were reduced by 7.5% while *best-case* HERS Index scores in climate zones 6-8 were reduced by 9.3% as compared with the 2009 IECC SRD, making up some of the relative ground lost during the 2009 IECC code cycle.

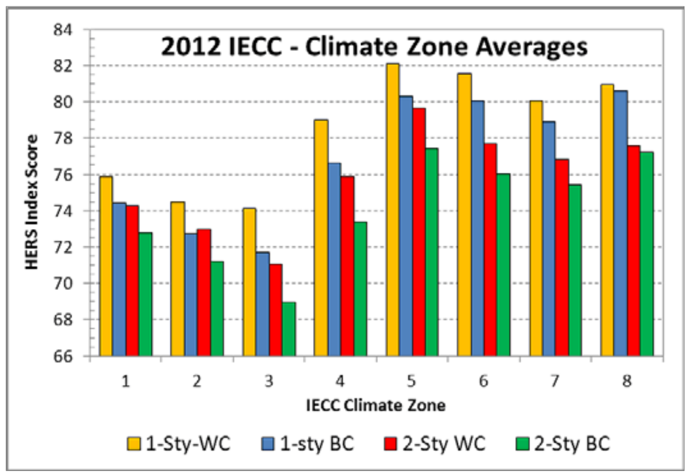

Figure 4. HERS Index scores for the 2012 IECC for 1-story and 2-story *worst-case* and *best-case* home models.

Going one step further with this analysis and including the new NAECA equipment standards with the 2012 IECC SRD, there is additional stringency gained but only in southern climates. For the 2012 IECC SRD with new NAECA standard equipment, average *best-case* HERS Index scores in climate zones 1-3 were reduced by 5.8% compared with the 2012 IECC while *best-case* HERS Index scores in climate zones 6-8 were not reduced at all. This lack of efficiency gains in northern climates is due to the fact that the gas furnace Rule was vacated by DOE.

Going all the way back to the 2006 IECC SRD, average *best-case* HERS Index scores for the revised NAECA standard equipment in climate zones 1-3 were reduced by 28.3% while *best-case* HERS Index scores in climate zones 6-8 were reduced by 17.2% as compared with the 2006 IECC SRD, making total gains in increased codes and standards stringency more disparate between northern and southern climates between 2006 and the full 2015 implementation of the revised NAECA equipment standards with the gas furnace Rule vacated.

We can also look at the overall data set in the form of a box and whisker plot where the standard deviation and maximum and minimum for each climate zone are also plotted. Figure 5 presents the results in this format for the *best-case* HERS Index scores across all climates and equipment scenarios.

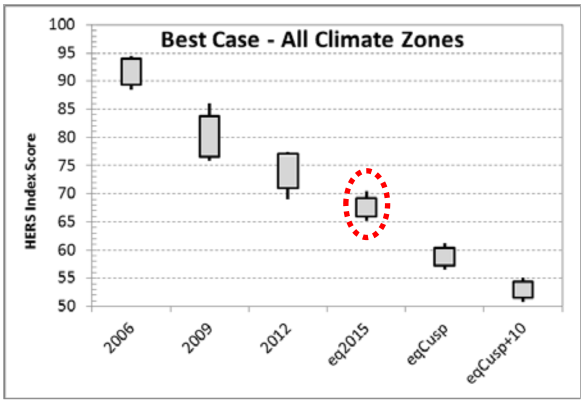

Figure 5a. Box and whisker plot showing HERS Index scores for options with original gas furnace Rule.

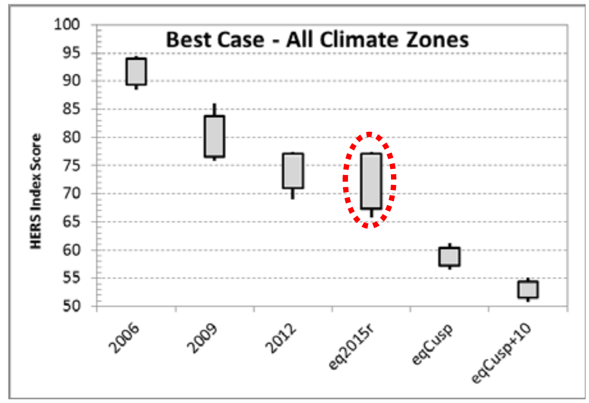

Figure 5b. Box and whisker plot showing HERS Index scores for options without gas furnace Rule.

Figure 5a shows that as efficiency increases, the variance in HERS Index score across climates tends to decrease. On the other hand, Figure 5b shows that vacating the furnace Rule substantially increases the variance across climate zones for the 'eq2015r' case. For Figure 5a, there is a clear reduction in variance in HERS Index scores across all climates starting with the eq2015 results. On the other hand Figure 5b shows an increase in the HERS score variance across climates when the gas furnace Rule is vacated.

Energy Savings

The energy savings associated with the HERS Index scores are calculated by subtracting the HERS Index scores for each successive option from the 2006 HERS Index scores and then dividing the difference by the 2006 HERS Index score. These savings for the *best-case* homes are shown in Figure 6.

Figure 6 shows a characteristic "droop" in the middle climate zones for most code versions and other options. However, as discussed with Figure 3, this droop does not exist for the 2009 IECC where incremental savings were concentrated in warm climates with much less savings in middle and northern climates. However, by 2012, the droop has reappeared to a certain degree.

Again, the differences between Figure 6a and 6b show the significance of vacating the gas furnace Rule, with the equipment-related savings for climate zones 5-8 disappearing with respect to the 2012 IECC. For climate zones 5-8, the losses in energy savings resulting from vacating the gas furnace Rule are as large as 12%.

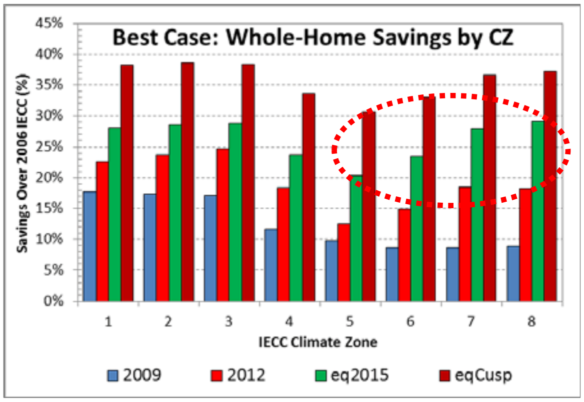

Figure 6a. Savings for options with respect to the 2006 IECC with the original gas furnace Rule.

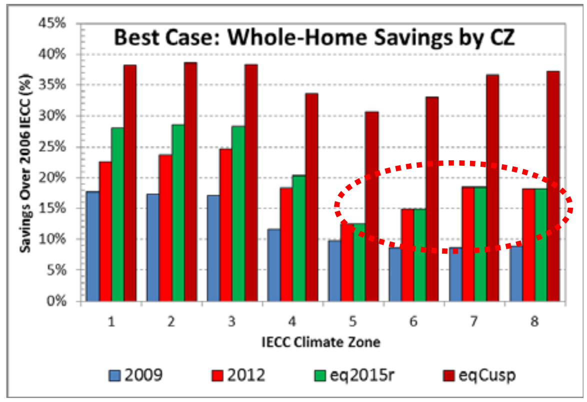

Figure 6b. Savings for options with respect to the 2006 IECC without the gas furnace Rule.

We can also look at the overall *best-case* savings data in the form of box and whisker plots where the standard deviation and maximum and minimum for each climate zone are also plotted. Figure 7 presents the results in this format.

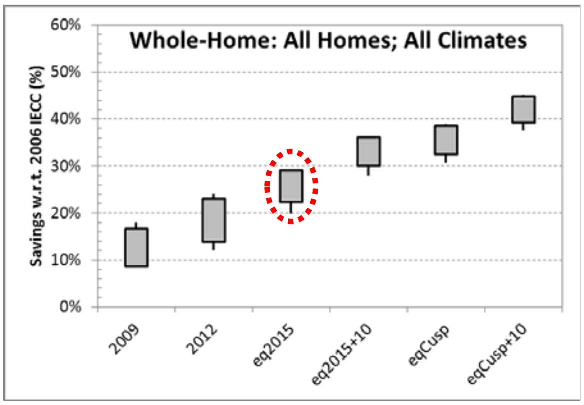

Figure 7a. Box and whisker plot showing savings associated with options with original gas furnace Rule.

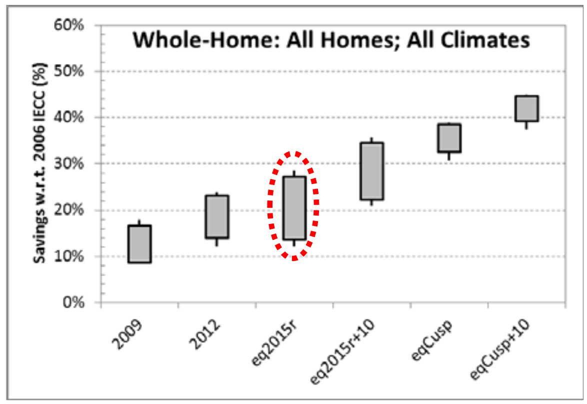

Figure 7b. Box and whisker plot showing savings associated with options without gas furnace Rule.

The x-axis labels in Figure 7a for ‘eq2015’ and ‘eqCusp’ are for the new NAECA standard equipment listed in Table 7a and the equipment on the cusp of broader market adoption listed in Table 8. Where a ‘+10’ is included, the values represent a 10% energy savings with respect to the given prefix. Figure 7b shows the same data with the gas furnace rule vacated (‘eq2015r’). The impact of vacating the gas furnace Rule is clear from the increase in standard deviation and the much lower minimum savings, which are equal to the 2012 minimum savings.

It is important to point out that the ‘eqCusp’ scenario is quite realistic given the penetration of ENERGY STAR new homes in the marketplace and the move on the part of new home builders to market their homes using the HERS Index. It is also interesting to note in Figure 7a that the average savings from ‘eqCusp’ are almost the same as the savings from ‘eq2015+10’, with mean savings of 35.7% and 33.4%, respectively.

Discussion

The HERS Reference Home, which provides the baseline building loads and energy consumption for comparison with the Rated Home, is based on the 2004 IECC Supplement. The 2006 IECC differs from the 2004 IECC Supplement in a significant way – the envelope leakages is less for the 2006 IECC than for the 2004 IECC Supplement (and the HERS Reference Home). For the 2004 IECC Supplement and the HERS Reference Home the envelope has a specific leakage area (SLA) of 0.00048 and for the 2006 IECC the SLA is 0.00036. An SLA of 0.00048 corresponds roughly to an ach50 of 9, while an SLA of 0.00036 corresponds roughly to and ach50 of 7. Depending on climate, this envelope leakage difference can make a substantial difference in building heating and cooling loads due to natural infiltration. This difference is climate zone dependent. For climate zones 1 and 2 there is little, if any, discernible score difference. But for climate zone 3, the average modeled home score was reduced by1.5 points, for climate zones 4 and 5, the average modeled home score was reduced by 3.3 points and for climate zones 6 through 8, the average modeled home score was reduced 5.0 points for IECC envelope leakage values.

There are other meaningful differences between the 2006 IECC models and the HERS Reference. These differences stem primarily from the configuration input assumptions. The HERS Reference Home (as well as the IECC reference) use U-factors to describe the thermal envelope components. This study, on the other hand, chose to use the R-Value tables from the 2006 IECC as input for the IECC models. In a number of cases these 2006 IECC component R-Value tables do not line up precisely with the 2006 IECC U-Factors equivalents that are used as the reference against which the modeled homes are compared. These same 2006 IECC U-Factor equivalents are used for the HERS Reference Home.

The most consistent example of this difference is the treatment of ceilings and attics. For reference homes the ceiling/roof component is given as a U-factor, where the U-Factor is defined as the indoor air to outdoor air component conductance. For single-assembly roof systems, the R-Value table will line up reasonably closely with the equivalent U-Factor reference prescribed by the IECC and HERS U-Factor tables. However, for vented attics, the attic space configuration adds additional thermal resistance. As a result, the choice to use the IECC R-Value table resulted in overall ceiling/roof U-factors that are less than the U-Factors prescribed by the U-Factor tables. For example, while the prescribed reference U-factor for ceilings in climate zones 1-3 is 0.035, the attic systems modeled using R-30 ceiling insulation results in an overall ceiling/roof U-factor of 0.031. This increased efficiency in the modeled homes over the reference contributed a fairly consistent average decrease of about 2 HERS points in all climates with slightly larger than average decreases in the most northern climates and slightly smaller than averages decreases in mid-latitude and southern climates.

When differences caused by both the ceiling/attic U-Factor and the SLA differences are combined, they result in fairly significant differences in average scores. These differences are again climate zone dependent due to the large climate dependence of the SLA difference. For climate zones 1 and 2 the average reduction in score for the modeled homes is 1.8 points, due almost entirely to the difference in ceiling/attic U-Factors. For climate zone 3, the average score reduction is 3.3 points, for climate zones 4 and 5, the average score reduction is 5.3 points and for climate zones 6 through 8, the average score reduction is 7.8 points.

Similar differences exist for wall systems. For walls, however, the differences are not systemic in the same manner. For some climates, the selection of 2006 IECC R-Values resulted in wall U-Factors that were greater than the reference U-Factor and in other climates the 2006 IECC wall R-Value selection resulted in U-Factors that were less than the reference U-Factor. In climate zones 1-4, for example, the 2006 R-Value table prescribes R-13cavity insulation. When combined with a standard framing fraction of 23%, this results in a wall U-Factor of 0.084, slightly greater the reference U-Factor of 0.082, making the modeled home slightly less efficient than its reference.

On the other hand, in climate zones 5-6, where R-13 cavity insulation plus R-5 sheathing was selected from the IECC 2006 R-value table, its U-factor of 0.057 is less than the reference U-Factor of 0.60, making the modeled home slightly more efficient than its reference. The HERS Index score changes resulting from these wall component differences in climate zones 1-6 were insignificant. However, for climate zones 7 and 8, where R-21 wall insulation was selected from the 2006 IECC R-value table, the difference between the modeled wall U-Factor and the reference U-factor was significant. With the default framing fraction of 23%, the modeled R-21 cavity insulation evaluates to an U-Factor of 0.067 while the reference U-Factor is 0.057. This constitutes a significant difference that results in an average increase in the modeled home HERS Index score of 2.5 points in climate zones 7 and 8.

Another difference exists between the 2006 IECC and the HERS references in climate zones 4-8. In these zones the reference SHGC for the IECC and HERS are different. For the 2006 IECC the NR (no requirement) entry in the table is specified to be 0.40 for the Standard Reference Design. However, for the HERS Reference Home, the technical committee that developed the HERS standard in 2005 voted to increase this value to 0.55 in climate zones 4-8 to increase the efficiency of the HERS Reference slightly for climates where solar gain is beneficial for heating. For climate zones 4 and 5, this difference resulted in only a 0.6 point increase in the modeled homes. However, for climate zone 6, the SGHC difference resulted in an increase of 1.5 points in the modeled homes and for climate zones 7 and 8, a 2.3 point increase was found.

As seen in Figures 2-4, there are also differences in scores between the one-story and two-story IECC models. These differences are a result of the fact that the HERS reference home is the geometric twin of the IECC model. Thus, even though the two-story IECC model uses somewhat more energy that the one-story model, its two-story geometric twin reference also uses more energy. Table 9 provides an example of this phenomenon.

Table 9: Energy Uses and Index Scores for one-story and two-story IECC 2012 Models in Chicago, IL (Climate Zone 5A)

1-Story, 2012 IECC Model				
Energy Use:	kWh	Therms	siteMBtu	srcMBtu*
Model	7,884	731	100.0	170.4
HERSref	9,426	853	117.5	201.4
Index Score:			85.1	84.6
2-Story, 2012 IECC Model				
Energy Use:	kWh	Therms	siteMBtu	srcMBtu*
Model	9,068	780	108.9	189.3
HERSref	11,143	941	132.1	230.7
Index Score:			82.5	82.1
Δ Index Score (1-Sty - 2-Sty) :			2.7	2.5

* Source multipliers: 3.365 for electricity and 1.092 for gas

Table 9 shows that the increase in site energy uses for the two-story HERS reference with respect to the one-story HERS reference is 12.5%. For the model home, this increase is 8.9%. The same is true for source energy use where the percentage increases are 14.6% and 11.1%.

The Index score for a home is determined by dividing the model home use by the reference home use. Where the denominator of the Index fraction increases by a larger percentage than the numerator, the Index score will decrease. This is a matter of mathematics, not a matter of the selected scoring method. As shown in Table 11, the Index scores are 2.7 and 2.5 points lower for the two-story home than the one-story home. Thus, where the objective is to determine the relative change in energy use of a model home with respect to a reference home of the same geometry, model homes with different geometries are not likely to produce the same Index score, even when all other attributes of the homes are identical.

Conclusions

The findings of the study show that there has been a steady and consistent increase in IECC Code stringency for residential buildings between 2006 and 2012 and that implementation of the new NAECA standards for hot water and space heating and cooling equipment will increase overall energy saving still further.

Best-Case HERS Index Scores

Table 10 presents the climate zone average HERS Index scores for the overall *best-case* configuration (2-story, north-south orientation). HERS Index scores decline with each successive generation of the IECC and again with the implementation of the latest NAECA standards. The impact of equipment that is on the cusp of greater market adoption reduces the HERS Index scores even further and initiatives like the DOE Challenge Home program will likely push the state-of-the-art in home construction to

HERS Index scores that are even 10% better than those for equipment that is on the cusp of wide-spread adoption.[2]

Table 10: *Best-Case* Climate Zone Average HERS Index Scores

Climates:	2006	2009	2012	eq2015r	eqCusp	eqCusp+10	% Wgt[3]
Zone 1	94	77	73	68	58	52	0.96%
Zone 2	93	77	71	67	57	52	21.43%
Zone 3	92	76	69	66	56	51	25.77%
Zone 4	90	79	73	72	60	54	22.76%
Zone 5	89	80	77	77	61	55	21.03%
Zone 6	90	82	76	76	60	54	6.79%
Zone 7	93	85	75	75	59	53	0.75%
Zone 8	94	86	77	77	59	53	0.50%
U.S. Average	92	80	74	72	59	53	n/a
U.S. Wgt'd Avg.	91	78	73	71	59	53	99.99%

Two sets of U.S. averages are provided. The first is a simple average and the second is a weighted average that uses the new home market share in each climate zone to weight the climate zone averages to a national average. Weighting factors used to derive the weighted averages are provided in the right-most column of Table 10. There are only small differences between the simple U.S averages and the weighted U.S. averages.

When market-ready, high-efficiency equipment that is on the cusp of wide-spread adoption due to the EPA ENERGY STAR and DOE Challenge Home programs is considered, energy savings are further increased. For these 'eqCusp' models, the U.S. average HERS Index score was 59. As previously shown in Figure 5, increasing energy savings by just 10%, results in *best-case* HERS Index scores with a U.S. average of 53. These HERS Index scores fairly closely represents the stated goal of the DOE Challenge Home program. As a result of the changes in the IECC and NAECA standards, such homes are likely to have achieved reasonable market penetration by 2015 when the new NAECA standards are fully implemented.

Ratings and Codes

Across the nation, state and local governments are adding a HERS Index Score target as a performance compliance option to their building energy code. To date code jurisdictions in the states of Arkansas, Colorado, Idaho, Kansas, New Mexico, New York and Massachusetts have incorporated a HERS Index Score option in their residential energy codes. For a listing of jurisdictions that have incorporated a HERS Index Score into their energy code see http://resnet.us/professional/main/Hers_index_and_energy_codes.

For jurisdictions attempting to establish a HERS Index Score compliance option that complies with the IECC, it is important to select an appropriate target value that ensures that most homes would be equivalent to or exceed energy savings of an IECC-compliant home. The 2009 and 2012 IECC do not award credit for heating, cooling, water heating

[2] For example, see U.S. DOE Challenge Home guidelines

[3] Personal communication with Craig Drumheller, NAHBRC, December 28, 2012.

or appliance upgrades, which do receive energy saving credits using the HERS method. Thus, a home that achieves a HERS 73 in climate zone 4, through a combination of envelope and equipment and appliance upgrades, will not necessarily achieve compliance with the 2012 IECC, which measures compliance based only on the thermal envelope efficiency with no credits for equipment or appliance upgrades.

HERS Index scores that are lower than the ‘eqCusp’ levels tend to account for HVAC equipment likely to be installed in the near future, irrespective of code requirements. These scores – an average of 60 – could be a reasonable option to consider as a target. A more conservative approach, and one that would increase the likelihood that most homes would be equivalent to the 2012 IECC, would be to use the ‘eqCusp+10’ values (an average of 54). Additionally, using a more conservative target value will allow the target to remain in place for longer without the need for revision as equipment, appliances, and other features improve.

Table 11 presents the overall climate zone average HERS Index score for all home configurations (*best-case*, *worst-case*, one-story and two-story) for each climate zone along with the U.S. simple average and weighted average scores for each version of the IECC and for the revised NAECA equipment standards (‘eq2015r’). These scores represent the average HERS Index scores that would result from compliance with the IECC under specific scenarios. For example, the 2009 and 2012 values represent the average HERS Index score in the absence of equipment or appliance upgrades and other features not considered by the IECC. As stated above, equipment upgrades are not uncommon in new homes. Thus, for a HERS score to assure compliance with the 2009 or 2012 IECC that score would need to be set significantly below these values, at levels shown in the last two columns of Table 11 (i.e., HERS 54-60 as a national average).

Table 11: Climate Zone Average HERS Index Scores for all Configurations

Climates	2006	2009	2012	eq2015r	eqCusp	eqCusp+10
Zone 1	97	79	74	69	59	53
Zone 2	96	79	73	68	58	53
Zone 3	94	78	71	68	58	52
Zone 4	92	82	76	74	61	55
Zone 5	91	82	80	80	63	57
Zone 6	92	83	79	79	62	56
Zone 7	93	85	78	78	60	54
Zone 8	96	86	79	79	61	54
U.S. Average	94	82	76	74	60	54
U.S. Wgt'd Avg.	93	80	75	73	60	54

The overall U.S. simple-average and weighted-average HERS Index scores presented in Table 11 are 1-2 HERS Index points greater than the *best-case* results presented in Table 10. A box and whisker plot of the data set from which Table 11 values are derived is shown in Figure 8.

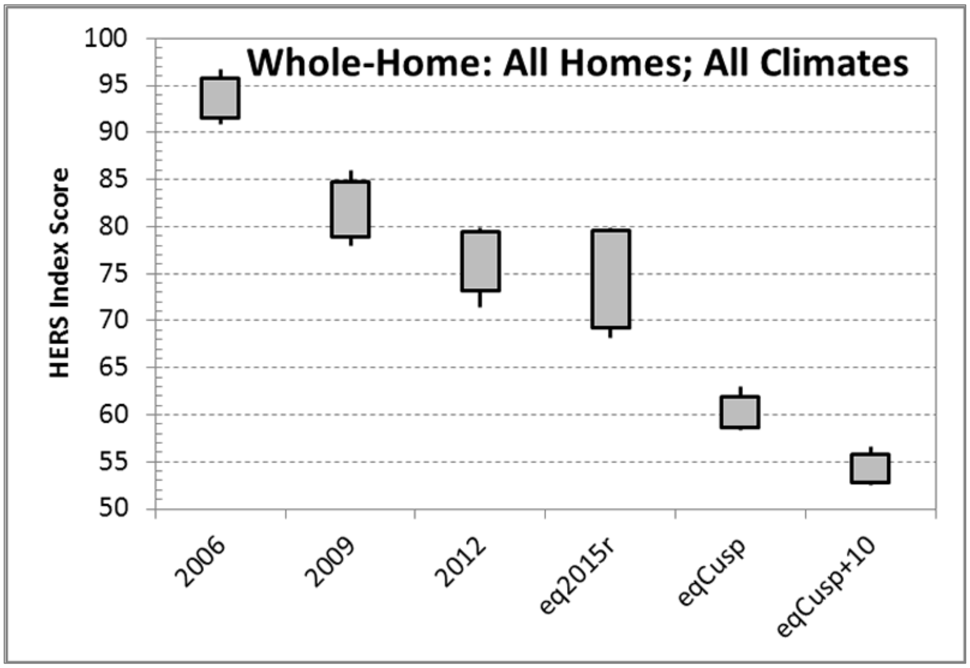

Figure 8. Box and whisker plot for all cases and all climate zones showing HERS Index scores for the versions of the IECC and equipment studied with gas furnace rule vacated.

Since the difference between the *best-case* and *worst-case* configurations consists of only a 90^{o} rotation of the home, this average is representative of the overall average likely to be achieved in new construction. Therefore, overall averages of the *best-case, worst-case* and one-story and two-story homes show the HERS Index score likely to result from compliance with the IECC if equipment and appliance credits are not considered. For jurisdictions that seek to tie code compliance to a HERS Index score that would include equipment and appliance trade-off credits, designating the HERS Index scores in the 'eqCusp' or preferably the 'eqCusp+10' column in Table 11 as the target will more likely to result in homes that achieve compliance with the various versions of the IECC.

One additional consideration is important. The HERS Index score represents whole-home energy use, while the IECC considers only the energy uses for space heating, space cooling, service hot water and lighting. The savings associated with whole-home energy use represented by the HERS Index include appliance energy end uses that are not considered by the IECC. As a result, the whole-home energy savings percentages determined through calculation of the HERS Index scores underestimate the energy savings percentage that would be attributable to only the IECC energy end uses. Fortunately, the appliance energy uses that are considered by the HERS Index scores are known quantities that can be removed from the raw HERS Reference Home and Rated Home data such that the Code-only savings can be calculated. Figure 9 shows the resulting savings as a box and whisker plot.

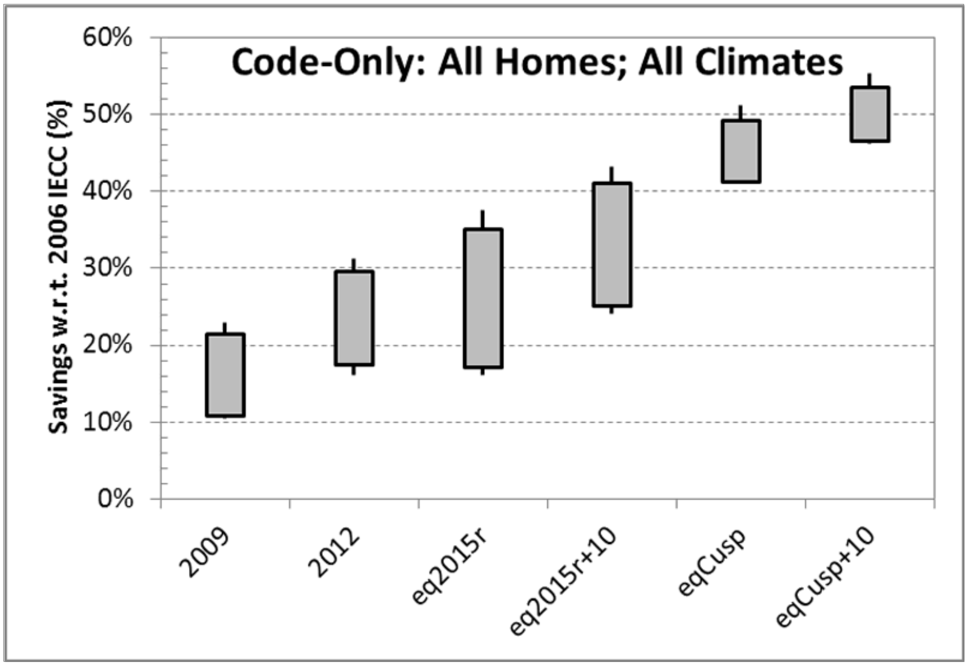

Figure 9. Box and whisker plot showing Code-only savings with respect to the 2006 IECC for the options studied with the gas furnace Rule vacated.

Again, we note that the variance for the revised 2015 equipment standards is significantly larger than for all other options. This occurs because vacation of only the gas furnace Rule results in no incremental savings over 2012 IECC in climate zones 5-8 but significant saving in warmer climate zones where the new heat pump cooling and heating efficiency standards remain in effect.

Finally it is illustrative to provide a summary plot of the climate weighted average savings for the U.S. as a whole. Figure 10 provides these data in a bar chart that illustrates not only the differences between the whole-home savings and the Code-only savings but also shows the impact of vacating the gas furnace Rule. Figure 10a provides data for the original NAECA standards including the gas furnace Rule and Figure 10b provides the same data and for the revised standards without the gas furnace Rule.

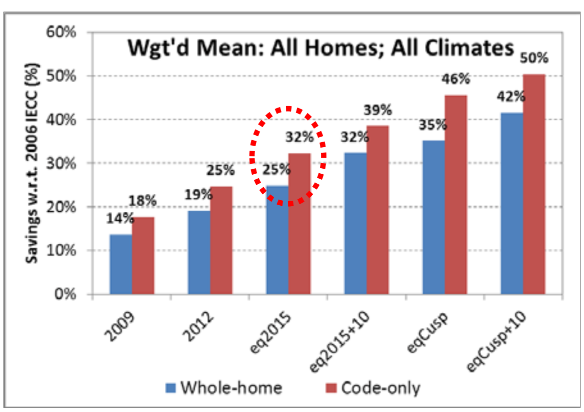

Figure 10a. Weighted mean energy savings with respect to 2006 IECC for options including the gas furnace Rule.

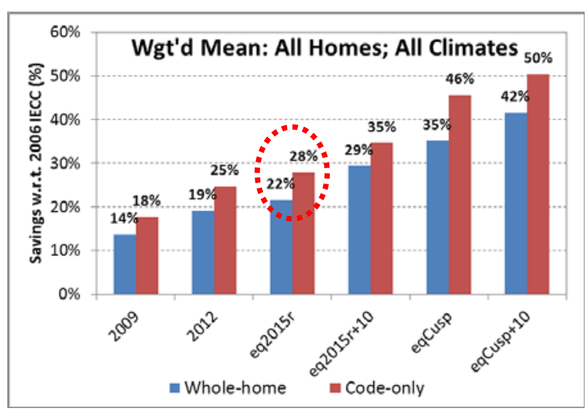

Figure 10a. Weighted mean energy savings with respect to the 2006 IECC for options excluding the gas furnace Rule.

One sees from Figure 10 that Code-only savings exceed whole-home savings by 4-5% for the 2009 and 2012 code. However, for the 'eqCusp' options the Code-only savings exceed the whole-home savings by 8-10%. This occurs because all of the savings from the 2009 and 2012 IECC are derived without benefit of improved heating and cooling system performance. On the other hand, the eqCusp options provide improved heating, cooling and water heating savings, reducing these energy uses as compared with the baseline (the 2006 IECC).

One additional insight that can be gleaned from Figure 10 is that it is indeed possible, and even reasonable, to expect that we can achieve savings of 50% as compared with the 2006 IECC – all it takes is a small increment of additional efficiency compared with equipment that is on the cusp of wide-spread adoption in the market.

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