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Analysis of Differences between 2018 IECC R406 Code Compliance and ANSI/RESNET/ICC Standard 301

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Background

The Residential Energy Services Network (RESNET) contracted with the Florida Solar Energy Center (FSEC) to conduct simulation analysis, evaluation and assessment of the Energy Rating Reference Home ventilation specification contained in Section R406.3 of the 2018 IECC. This 2018 IECC specification differs from the Energy Rating Reference Home ventilation specification of ANSI/RESNET/ICC 301-2014 and RESNET desires to understand the impact of the difference. An in-house version of EnergyGauge® USA (v.6.0.04) that is configured to incorporate the 2018 IECC R406.3 Reference Home ventilation specification is used to conduct the simulation analysis.

Abstract

EnergyGauge USA is used to study outdoor air ventilation rates in energy-efficient, one-story 2000 ft^2, 3-bedroom, single-family homes in sixteen representative U.S. cities. Each of the 16 home archetypes is configured to be minimally compliant with the score requirements of Table R406.4 of the 2018 IECC as determined in accordance with ANSI/RESNET/ICC 301-2014. Each home is also configured to comply using two different compliance methods: the first with only high-efficiency options and the second utilizing on-site photovoltaic power generation. Each home configuration is evaluated using the ANSI/RESNET/ICC 301 Reference Home ventilation specification and again using the 2018 IECC R406.3 Reference Home ventilation specification. Results from the simulations are used to conduct analysis and evaluation of the impacts of the 2018 IECC R406.3 Reference Home ventilation specification on the index scores of the home archetypes in the 16 representative TMY cities.

Methodology

One-story, 2000 ft^2, 3-bedroom frame homes are configured to be minimally compliant with the score requirements of Table R406.4 of the 2018 IECC using the provisions of ANSI/RESNET/ICC 301-2014. These archetypical homes are configured in two ways: with on-site photovoltaics (PV) and without on-site PV but with high efficiency (HE) equipment. This is done because Section 406 of 2018 IECC requires that different minimum envelope constraints be met depending on whether or not photovoltaic (PV) power generation is used to achieve the required compliance scores. If on-site renewables (PV) are not used to achieve compliance, the minimum envelope requirements are as specified by the 2009 IECC. However, if on-site renewables are used to achieve compliance, the minimum envelope requirements are those of the 2015 IECC. Therefore, the analysis employs two home archetypes in each of 16 cities: one with on-site renewables and one without on-site renewables.

Section R406.3 provisions of the 2018 IECC are as follows:

> "**R406.3 Energy Rating Index.** The Energy Rating Index (ERI) shall be determined in accordance with RESNET/ICC 301 except for buildings covered by the *International Residential Code*, the ERI Reference Design Ventilation rate shall be in accordance with Equation 4-1.
>
> Ventilation rate, CFM = (0.01 x total square foot area of house)
> + [7.5 x (number of bedrooms +1)] **(Equation 4-1)**"

Where Ventilation is defined by the 2018 IECC as follows:

> "The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space."

The provisions of ANSI/RESNET/ICC 301 differ with regard to the ventilation rate specification whereby the minimum Energy Rating Reference Home specification in the RESNET Standard is effectively as follows:

> Ventilation rate, CFM = (0.03 x total square foot area of the house)
> + [7.5 x (number of bedrooms + 1)]

This results in a clear difference in the Reference case ventilation rate between the 2018 IECC and the ANSI/RESNET/ICC 301-2014 Standard. This study is designed to evaluate that difference for a number of climatic locations across the Nation under specific sets of conditions.

ANSI/RESNET/ICC 301-2014 establishes the total ventilation rate in the Reference Home by specifying a Specific Leakage Area (SLA) for the envelope of 0.00036 and requiring that any additional ventilation air needed to meet the minimum ventilation requirement specified by Equation (4.6) of ASHRAE Standard 62.2-2013 be added to the infiltration rate resulting from the specified SLA of the building envelope. Equation (4.6) of ASHRAE 62.2-2013 is as follows:

$$Qfan = Qtot - Qinf$$

where

Qfan = required mechanical ventilation rate (cfm)
$Qtot = 0.03 \cdot Afloor + 7.5(Nbr + 1)$ = total required ventilation rate (cfm)
Qinf = infiltration rate which may be no greater than $2/3 \cdot Qtot$ (cfm)
Afloor = conditioned floor area (ft^2)
Nbr = number of bedrooms

And from Equation (4.5a) of the same standard:

$$Qinf = (NL \cdot wsf \cdot Afloor) / 7.3$$

where

NL = normalized leakage = $1000 \cdot (ELA / Afloor) \cdot [H / Hr]^z$
wsf = weather and shielding factor from Normative Appendix B of the same Standard
ELA = effective leakage area (ft^2) at 4 Pa pressure difference
H = vertical distance between lowest and highest above-grade points within the pressure boundary (ft.)
Hr = reference height = 8.202 ft.
z = 0.4 for the purpose of calculating the Effective Annual Infiltration Rate *(Qinf)*

Thus, the total effective ventilation rate in the ANSI/RESNET/ICC 301-2014 Reference Home is at least 0.03·Afloor + 7.5(Nbr+1) but can be slightly larger in climates where '*wsf*' is large enough to cause the *2/3·Qtot* rule in ASHRAE 62.2-2013 equation (4.6) to be invoked.

ANSI/RESNET/ICC 301-2014 also specifies that the fan power for the Reference Home shall be equal to the mechanical ventilation fan air flow rate (*Qfan*) in the Rated Home times a fan power value that is dependent on the type of mechanical ventilation system in the Rated Home. For the analysis conducted here, all Rated Homes are assumed to have continuous balanced mechanical ventilation systems with fan power equal to the Reference Home fan power specification of 0.7 watts per cfm.

Section R406.3 of IECC 2018 specifies only a total ventilation rate. Therefore, the analysis conducted here treats the IECC Reference Home ventilation specification with the same fan power used by ANSI/RESNET/ICC 301-2014 of 0.7 watts per cfm (i.e. balanced, continuous mechanical ventilation).

In summary, there are two different archetype homes in each of the 16 climates for a total of 32 different home configurations and there are 2 different reference cases for each home for a total of 64 home configurations.

Tables 1 through 8 present the characteristics for the 64 different home configurations used in the simulation analysis.

Table 1: General Home Characteristics

Component	**Value**
Total floor area (ft^2)	2,000
Average ceiling height (ft.)	9
Total volume (ft^3)	18,000
N-S wall length (ft.)	50
E-W wall length (ft.)	40
Door area (ft^2)	40
Window/floor area (%)	15%
Total window area (ft^2)	300
N-S window fraction (%)	35%
E-W window fraction (%)	15%

Table 2: 2009 IECC Minimum Envelope 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

LOCATION	IECC CZ	Ceiling R-value	Wall R-value	Found. type	Slab R-value	Floor R-value	Fen U-Factor	Fen SHGC
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

Notes for Tables 2-3:

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: 2015 IECC Minimum Envelope 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 4: Additional IECC Minimum Characteristics

Item	2009 IECC	2015 IECC
Envelope Leakage	7 ach50	CZ 1-2: 5 ach50 CZ 3-8: 3 ach50
Programmable Thermostat	Yes	Yes
High Efficiency Lighting	50%	75%
Hot Water Pipe Insulation	No	Yes
Max Window/Floor area	15%	15%
Sealed Air Handlers	No	Yes

Table 5: High-Efficiency Home Equipment Characteristics
(All homes: 100% high efficiency lighting plus
ENERGY STAR refrigerator, clothes washer and dishwasher)

LOCATION	IECC CZ	IECC ERI	Heating System		Cooling System		Water Heater	
			Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	57	elec	8.2	elec	14.0	HPWH	2.50
Orlando, FL	2A	57	elec	8.2	elec	15.0	HPWH	2.50
Houston, TX	2A	57	elec	8.2	elec	14.0	HPWH	2.50

LOCATION	IECC CZ	IECC ERI	Heating System		Cooling System		Water Heater	
			Fuel	Eff	Fuel	SEER	Fuel	EF
Phoenix, AZ	2B	57	elec	8.2	elec	14.0	HPWH	2.50
Charleston, SC	3A	57	elec	8.2	elec	14.0	HPWH	2.50
Charlotte, NC	3A	57	gas	83%	elec	14.0	T'less gas	0.83
Ok. City, OK	3A	57	gas	85%	elec	14.0	T'less gas	0.83
Las Vegas, NV	3B	57	gas	85%	elec	14.0	T'less gas	0.83
Baltimore, MD	4A	62	gas	83%	elec	14.0	T'less gas	0.83
Kansas City, MO	4A	62	gas	85%	elec	13.0	T'less gas	0.83
Chicago, IL	5A	61	gas	93%	elec	13.0	T'less gas	0.83
Denver, CO	5B	61	gas	91%	elec	13.0	T'less gas	0.83
Minneapolis, MN	6A	61	gas	93%	elec	13.0	T'less gas	0.83
Billings, MT	6B	61	gas	93%	elec	13.0	T'less gas	0.83
Fargo, ND	7A	58	gas	95%	elec	13.0	T'less gas	0.83
Fairbanks, AK	8	58	gas	95%	elec	13.0	T'less gas	0.83

Notes for Tables 5 and 6:

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 6: Renewable Energy Home Equipment Characteristics
(All homes: 75% high efficiency lighting plus
HERS Reference Appliances)

LOCATION	IECC CZ	IECC ERI	Heating System		Cooling System		Water Heater	
			Fuel	Eff	Fuel	SEER	Fuel	EF
Miami, FL	1A	57	elec	8.2	elec	14	elec (50)	0.95
Orlando, FL	2A	57	elec	8.2	elec	14	elec (50)	0.95
Houston, TX	2A	57	elec	8.2	elec	14	elec (50)	0.95
Phoenix, AZ	2B	57	elec	8.2	elec	14	elec (50)	0.95
Charleston, SC	3A	57	elec	8.2	elec	14	elec (50)	0.95
Charlotte, NC	3A	57	gas	80%	elec	14	gas (40)	0.62
Ok. City, OK	3A	57	gas	80%	elec	14	gas (40)	0.62
Las Vegas, NV	3B	57	gas	80%	elec	14	gas (40)	0.62
Baltimore, MD	4A	62	gas	80%	elec	14	gas (40)	0.62
Kansas City, MO	4A	62	gas	80%	elec	13	gas (40)	0.62
Chicago, IL	5A	61	gas	80%	elec	13	gas (40)	0.62
Denver, CO	5B	61	gas	80%	elec	13	gas (40)	0.62
Minneapolis, MN	6A	61	gas	80%	elec	13	gas (40)	0.62
Billings, MT	6B	61	gas	80%	elec	13	gas (40)	0.62
Fargo, ND	7A	58	gas	80%	elec	13	gas (40)	0.62
Fairbanks, AK	8	58	gas	80%	elec	13	gas (40)	0.62

Table 7: High Efficiency Home Air Exchange Rates

LOCATION	IECC CZ	IECC ERI	Outdoor Air Exchange Rate				
			ach50	wsf	Qinf	Qfan	Qtot
Miami, FL	1A	57	7	0.41	46.6	43.4	90.0
Orlando, FL	2A	57	7	0.42	47.7	42.3	90.0
Houston, TX	2A	57	7	0.39	44.3	45.7	90.0
Phoenix, AZ	2B	57	7	0.43	48.8	41.2	90.0
Charleston, SC	3A	57	7	0.43	48.8	41.2	90.0
Charlotte, NC	3A	57	7	0.43	48.8	41.2	90.0

LOCATION	IECC CZ	IECC ERI	Outdoor Air Exchange Rate				
			ach50	wsf	Qinf	Qfan	Qtot
Ok. City, OK	3A	57	7	0.61	69.3	30.0	99.3
Las Vegas, NV	3B	57	7	0.55	62.5	30.0	92.5
Baltimore, MD	4A	62	7	0.50	56.8	33.2	90.0
Kansas City, MO	4A	62	7	0.60	68.2	30.0	98.2
Chicago, IL	5A	61	7	0.60	68.2	30.0	98.2
Denver, CO	5B	61	7	0.63	67.0	30.0	97.0
Minneapolis, MN	6A	61	7	0.63	71.6	30.0	101.6
Billings, MT	6B	61	7	0.66	75.0	30.0	105.0
Fargo, ND	7A	58	7	0.69	78.4	30.0	108.4
Fairbanks, AK	8	58	7	0.70	79.5	30.0	109.5

Table 8: PV Home Installed PV Watts and Air Exchange Rates

LOCATION	IECC CZ	IECC ERI	PV Watts	Outdoor Air Exchange Rate				
				ach50	wsf	Qinf	Qfan	Qtot
Miami, FL	1A	57	1,275	5	0.41	33.3	56.7	90.0
Orlando, FL	2A	57	1,350	5	0.42	34.1	55.9	90.0
Houston, TX	2A	57	1,125	5	0.39	34.1	55.9	90.0
Phoenix, AZ	2B	57	750	5	0.43	34.9	55.1	90.0
Charleston, SC	3A	57	750	3	0.43	20.9	69.1	90.0
Charlotte, NC	3A	57	750	3	0.43	20.9	69.1	90.0
Ok. City, OK	3A	57	675	3	0.61	29.7	60.3	90.0
Las Vegas, NV	3B	57	375	3	0.55	26.8	63.2	90.0
Baltimore, MD	4A	62	1,275	3	0.50	24.3	65.7	90.0
Kansas City, MO	4A	62	1,275	3	0.60	29.2	60.8	90.0
Chicago, IL	5A	61	2,625	3	0.60	29.2	60.8	90.0
Denver, CO	5B	61	1,950	3	0.63	28.7	61.3	90.0
Minneapolis, MN	6A	61	2,550	3	0.63	30.7	59.3	90.0
Billings, MT	6B	61	2,175	3	0.66	32.1	57.9	90.0
Fargo, ND	7A	58	3,300	3	0.69	33.6	56.4	90.0
Fairbanks, AK	8	58	6,600	3	0.70	34.1	55.9	90.0

Findings

The principle finding from the study is that use of the 2018 IECC R406.3 specification for Reference Home ventilation increases the homes' index scores between 2.4 and 9.0 points compared with the index score of ANSI/RESNET/ICC 301-2014. The index score increase is found to be strongly dependent on weather conditions with homes in cold climates experiencing much larger increases than homes in warm climates.

Figure 1 shows the index score difference for both PV homes and HE homes as a function of climate severity (HDD_{65}). They behave in an almost identical fashion. Since the PV homes have much tighter envelopes, they require more mechanical ventilation. As a result, the mechanical ventilation requirement is greater for the PV homes than for the HE homes, compensating for the differences in envelope tightness. However, the Rated Home mechanical ventilation impact is small compared to the change induced by the significant reduction in Reference Home ventilation air flow, which is 50 cfm for the IECC case as compared with 90 cfm for the Standard 301 case.

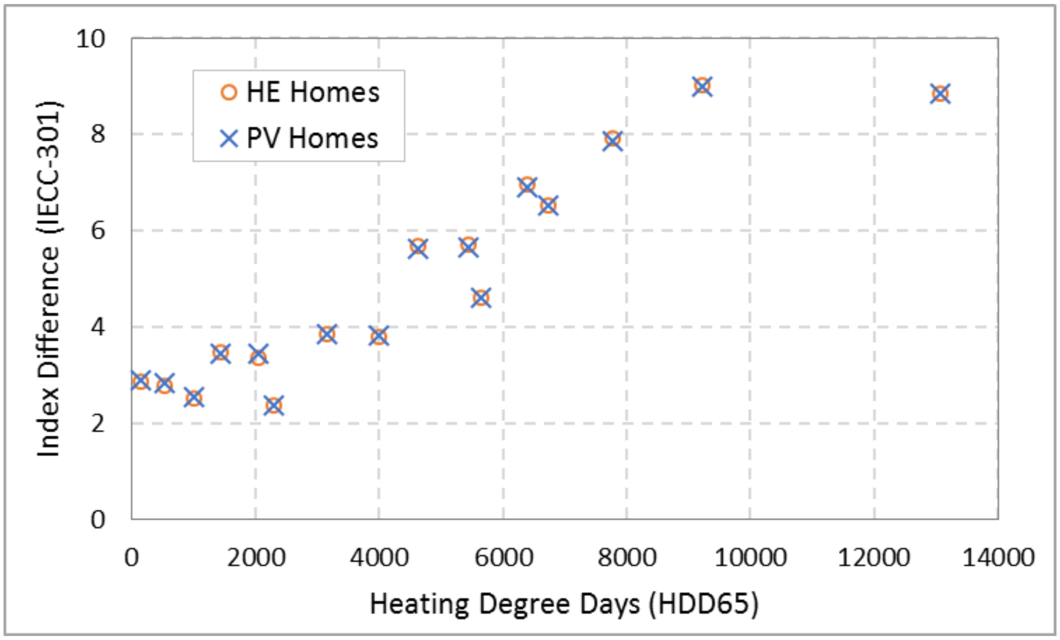

Figure 1: Index score increase for High Efficiency (HE) homes and photovoltaic (PV) Homes due to 2018 IECC R406.3 Reference Home ventilation specification.

One additional observation in Figure 1 is that there is reasonable correlation between the Index score increase and HDD_{65} between 2000 and 10,000. Data from climates with fewer than 2000 HDD and greater than 10,000 appear almost to be outliers in this data cohort.

Discussion

The increase in index scores shown in Figure 1 occur because the Reference Home energy consumption is decreased by the reduction in outdoor air exchange resulting from the 2018 IECC specification for Reference Home ventilation. Tables 9 and 10 illustrate the fact that all the increases in the index score result from a reduction in the energy consumption of the Reference Home case. Table 9 presents total home energy use results from the two cases simulated: the 301 HERS case and the 2018 IECC case. The differences in energy consumption (IECC case – 301 HERS case) are given for both the Reference and the Rated Homes. Note that the difference in total home energy use for the Rated home is zero in all cases. Figure 10 provides the same data for the HE Home cases.

Table 9: Total Home Energy Consumption (MBtu) for PV Homes

City	HDD_{65}	Reference Homes			Rated Homes		
		301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	150	54.2	52.5	-1.7	39.1	39.1	0.0
Houston	1439	53.4	51.2	-2.2	38.5	38.5	0.0
Orlando	526	48.7	47.3	-1.4	35.1	35.1	0.0
Phoenix	997	60.2	58.3	-1.9	41.3	41.3	0.0
Charleston	2051	57.0	54.6	-2.4	39.2	39.2	0.0
Charlotte	3153	93.6	85.7	-7.9	62.1	62.1	0.0
Oklahoma City	3993	115.7	106.5	-9.2	75.5	75.5	0.0

City	HDD_{65}	Reference Homes			Rated Homes		
		301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Las Vegas	2301	83.7	79.2	-4.5	55.3	55.3	0.0
Baltimore	4631	105.7	94.1	-11.6	78.7	78.7	0.0
Kansas City	5434	120.3	107.5	-12.8	89.5	89.5	0.0
Chicago	6399	125.1	109.9	-15.2	101.0	101.0	0.0
Denver	5655	104.1	94.9	-9.3	86.0	86.0	0.0
Minneapolis	7783	142.9	123.8	-19.1	111.8	111.8	0.0
Billings	6732	123.5	109.1	-14.4	97.7	97.7	0.0
Fargo	9211	165.3	140.1	-25.2	127.9	127.9	0.0
Fairbanks	13072	225.5	193.0	-32.5	177.3	177.3	0.0

Table 10: Total Rated Home Energy Consumption (MBtu) for HE Homes

City	HDD_{65}	Reference Homes			Rated Homes		
		301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	150	54.1	52.5	-1.7	31.9	31.9	0.0
Houston	1439	53.3	51.2	-2.2	31.4	31.4	0.0
Orlando	526	48.7	47.3	-1.4	28.6	28.6	0.0
Phoenix	997	60.1	58.3	-1.9	35.2	35.2	0.0
Charleston	2051	56.7	54.3	-2.4	33.2	33.2	0.0
Charlotte	3153	93.1	85.2	-7.9	57.4	57.4	0.0
Oklahoma City	3993	115.2	105.9	-9.2	70.8	70.8	0.0
Las Vegas	2301	83.0	78.5	-4.5	50.6	50.6	0.0
Baltimore	4631	105.2	93.6	-11.6	70.1	70.1	0.0
Kansas City	5434	119.7	106.9	-12.8	78.8	78.8	0.0
Chicago	6399	124.6	109.4	-15.2	84.1	84.1	0.0
Denver	5655	103.6	94.4	-9.3	69.6	69.6	0.0
Minneapolis	7783	142.5	123.4	-19.1	95.7	95.7	0.0
Billings	6732	123.1	108.8	-14.4	82.5	82.5	0.0
Fargo	9211	164.9	139.7	-25.2	105.7	105.7	0.0
Fairbanks	13072	225.2	192.7	-32.5	144.2	144.2	0.0

Tables 9 and 10 clearly show that the differences observed in the index scores are due only to changes in the Reference Home. The energy consumption values for the Rated Homes are identical, with all differences in energy consumption accruing to the Reference Homes. The sole change to the Reference Home is the treatment of its ventilation specification where it is either as specified by Standard 301 or as specified by R406.3 of the 2018 IECC.

Energy consumption is not the sole determinant of the rating index. Rather the denominator of the scoring fraction is the Total Reference Home building loads (TRL). Figure 2 illustrates how these building loads are changed through the use of the 2018 IECC R406.3 Reference Home ventilation specification as compared with the Standard 301 specification.

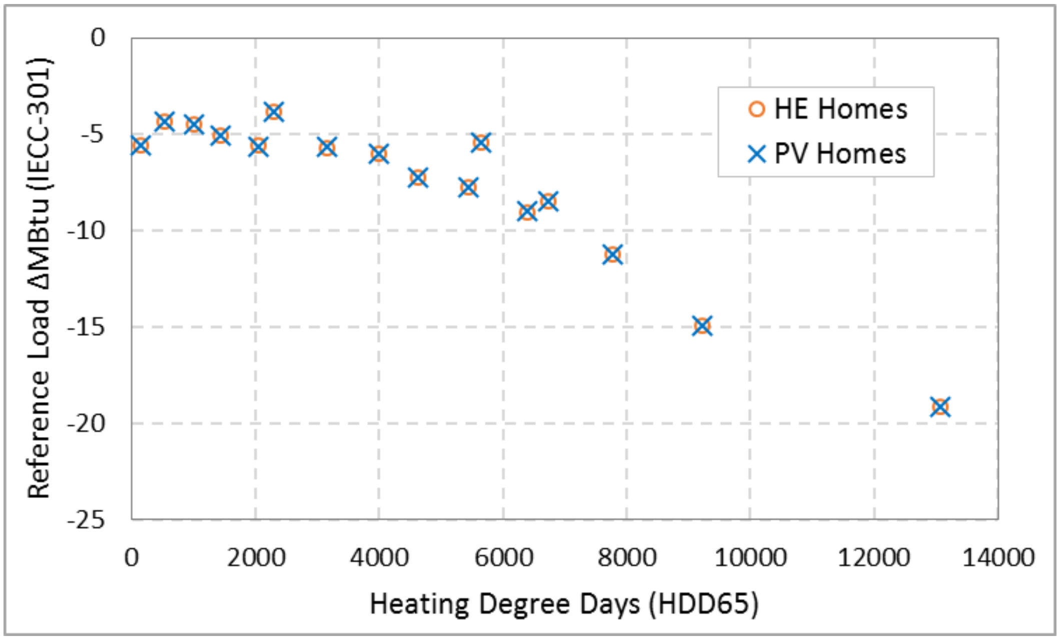

Figure 2: Differences in total building load for photovoltaic (PV) and High Efficiency (HE) homes due to IECC Reference Home ventilation specification.

Reductions in Reference Home total building loads are virtually the mirror image of the index scores seen in Figure 1. Since these loads serve as the denominator of the fraction that determines the index score, it is clear why the index score is increased by the 2018 IECC R406.3 Reference Home ventilation specification.

One additional set of data are analyzed in this study. ANSI/RESNET/ICC 301-2014 requires that both the Rated Home and the Reference Home have sufficient ventilation for acceptable indoor air quality. For the 2,000 ft^2, 3-bedroom homes used for this study, the ventilation air flow required for acceptable indoor air quality is 90 cfm.[1]

Since it is impossible to have constant ventilation due to external climatic influences, this value is specified as an annual average air exchange rate where the effective annual average infiltration rate combines with the constant mechanical ventilation rate to produce the required annual average needed.

As a result, for hourly simulations, one does not expect to see total air exchange values that are 90 cfm each hour. In fact, the hourly air exchange rate will vary by a substantial amount based on the leakiness of the home and the climate in which it is located. The climate provides the driving forces for infiltration in the form of indoor-to-outdoor temperature differences (which cause stack forces between the bottom and the top of home volumes) and the outdoor wind velocities (which cause wind pressure differences between the different faces of the home).

The leakiness of the envelope provides the holes through which these external conditions cause air to flow in the form of infiltration. So both the climate and the envelope leakage are important to infiltration air flow. We can measure the leakiness of the envelope to determine the Effective Leakage Area (ELA) and we can anticipate the impact of climate and building height using the calculation procedures provided by Equation (4.5a) of ANSI/ASHRAE Standard 62.2.

[1] This value based on Equation (4.1a) of ANSI/ASHRAE Standard 62.2-2016 for the total ventilation rate for acceptable indoor air quality.

For the homes evaluated in this study, the envelope leakage is prescribed in Table 7 for the High Efficiency (HE) homes and in Table 8 for the photovoltaic (PV) homes. The leakiness of these two sets of homes is significantly different in most cases (7 ach50 for the HE Homes versus 3 ach50 for the PV Homes). The leakiness of the ANSI/RESNET/ICC 301 Reference Home for these cases is 6.3 ach50, making the PV homes tighter than the 301 Reference Home and the HE homes slightly more leaky than the 301 Reference Home.

Figure 3 illustrates the interaction between climate and envelope leakiness for the PV Home in Denver, CO. The y-axis scales are purposefully the same to show the significant reduction in hourly infiltration variation resulting from a significantly tighter envelope. For the Denver Reference Home chart on the left, the 2018 IECC R406.3 Reference Home ventilation rate is also shown as a dotted purple line with a value of 50 cfm. The reduction in outdoor air exchange this case is from an annual average rate of 87 cfm to a constant rate of 50 cfm. This is a significant decrease in the outdoor air exchange rate for the Reference Home and results in the significant decrease in the building loads seen in Figure 2 above.

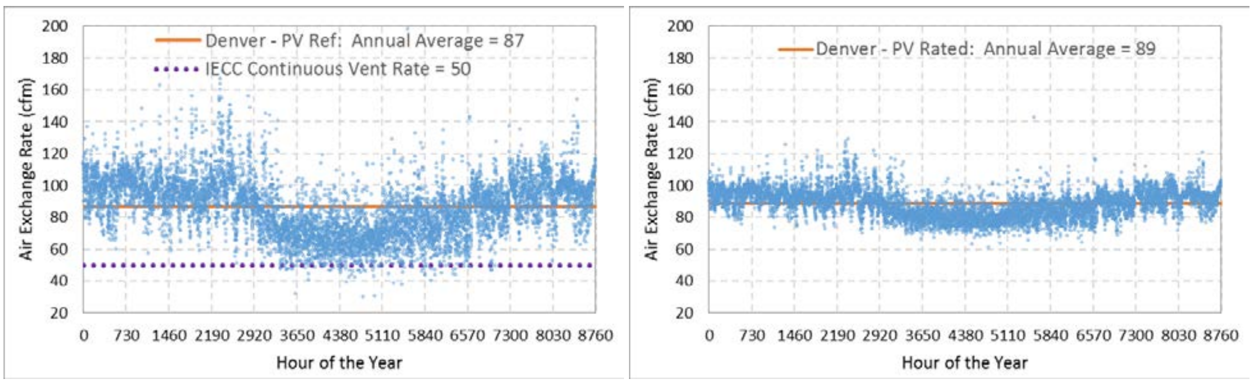

Figure 3. Hourly total outdoor air exchange rates for the Reference and the Rated PV Home in Denver, CO, showing the reduction in hourly outdoor air exchange rate variation caused by the much tighter building envelope of the Rated Home (6.3 ach50 vs. 3.0 ach50).

Similar hourly air exchange data are available for the High Efficiency (HE) homes where the Rated Home envelope is actually slightly leakier than the Reference Home (7 ach50 for the Rated Home vs. 6.3 ach50 for the Reference Home). Figure 4 provides the hourly data for this home. The annual average total air exchange rate for the HE home is actually larger than the annual average total air exchange rate for the PV home in Denver. This is due to the fact that the HE home in Denver falls victim to the 2/3rd rule, whereby only 2/3 of the total ventilation requirement may be met by infiltration. This factor is clearly evident in the data provided in Table 7 for the air exchange rates for the HE home in Denver (and other cold climate locations). Also note in Figure 4 that the air exchange data for the Reference Home is identical to that of the Reference Home in Figure 3.

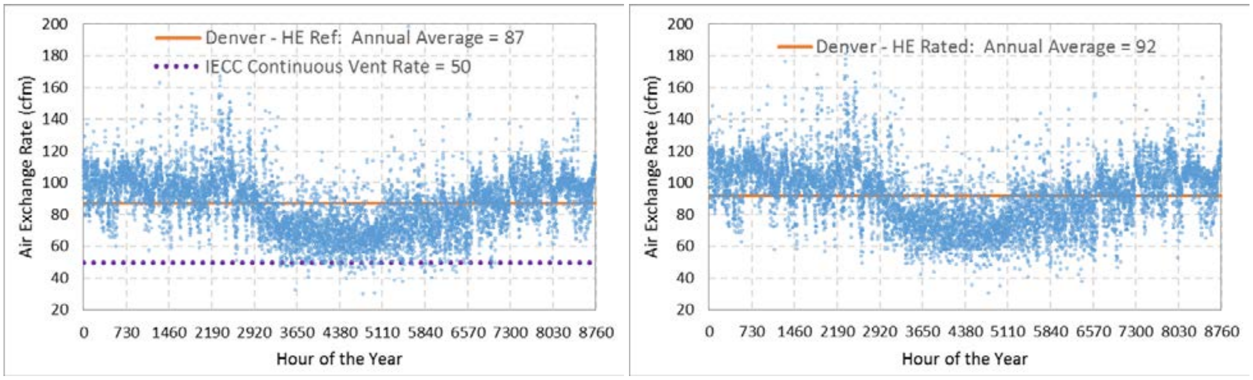

Figure 4. Hourly total outdoor air exchange rates for the Reference and the Rated HE Home in Denver, CO, showing the hourly outdoor air exchange rate when the envelope leakage values are similar (6.3 ach50 vs. 7.0 ach50).

Additional study results data are given in Appendix A.

Conclusions

The conclusions that are reached through evaluation of the data resulting from this study are as follows:

- Use of the 2018 IECC R406.3 specification for the ventilation rate in the Reference Home will likely result in a 2 to 10 point increase in the index score as compared with the index score from ANSI/RESNET/ICC 301-2014
- Whether the envelope complies with the 2009 IECC minimum requirements (HE homes) or with the 2015 IECC minimum requirements (PV homes) has no significant influence on the index point increase induced by the 2018 IECC R406.3 Reference Home ventilation specification.

References

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Appendix A

Detailed Simulation Results Data

Table A-1: Rating Index Values and differences between IECC and Standard 301 for all homes.

Rating Index Values	PV Homes			HE Homes		
	301 HERS	2018 IECC	Delta Index	301 HERS	2018 IECC	Delta Index
Miami	57.3	60.2	2.9	57.1	59.9	2.9
Houston	57.0	60.5	3.5	56.8	60.3	3.5
Orlando	57.4	60.3	2.9	56.8	59.6	2.8
Phoenix	57.1	59.7	2.5	56.9	59.4	2.5
Charleston	57.2	60.6	3.5	56.5	59.9	3.4
Charlotte	56.9	60.8	3.9	56.9	60.7	3.9
Oklahoma City	57.4	61.3	3.8	56.8	60.6	3.8
Las Vegas	57.3	59.7	2.4	56.8	59.2	2.4
Baltimore	61.7	67.4	5.6	62.0	67.7	5.7
Kansas City	62.0	67.7	5.7	61.6	67.3	5.7
Chicago	61.4	68.3	6.9	61.4	68.3	7.0
Denver	61.1	65.7	4.6	60.8	65.4	4.6
Minneapolis	61.2	69.1	7.9	61.1	69.0	7.9
Billings	61.0	67.5	6.5	60.8	67.3	6.5
Fargo	58.1	67.1	9.0	58.1	67.2	9.0
Fairbanks	58.4	67.3	8.9	58.3	67.2	8.9

Table A-2: Reference Home total building loads and differences between IECC and Standard 301 for all homes.

Reference Home Total Loads	PV Homes (MBtu)			HE Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	87.4	81.8	-5.6	87.1	81.5	-5.6
Houston	75.6	70.5	-5.1	75.3	70.2	-5.1
Orlando	69.1	64.7	-4.3	68.8	64.5	-4.4
Phoenix	96.5	91.9	-4.5	96.1	91.6	-4.5
Charleston	80.8	75.2	-5.6	80.2	74.6	-5.6
Charlotte	81.1	75.4	-5.7	80.6	74.9	-5.7
Oklahoma City	96.9	90.9	-6.1	96.4	90.3	-6.1
Las Vegas	91.6	87.8	-3.8	91.0	87.1	-3.8
Baltimore	83.0	75.7	-7.3	82.4	75.2	-7.3
Kansas City	91.0	83.3	-7.8	90.5	82.7	-7.8
Chicago	86.6	77.6	-9.0	86.1	77.0	-9.0
Denver	75.3	69.9	-5.4	74.8	69.4	-5.5
Minneapolis	96.0	84.7	-11.2	95.5	84.3	-11.2
Billings	85.0	76.5	-8.5	84.6	76.1	-8.5
Fargo	107.9	93.0	-14.9	107.5	92.6	-14.9
Fairbanks	141.6	122.4	-19.2	141.3	122.1	-19.2

Table A-3: PV Home heating energy consumption and differences between IECC and Standard 301 for all homes.

PV Homes Heating Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	0.3	0.2	-0.1	0.1	0.1	0.0
Houston	6.0	4.8	-1.2	3.9	3.9	0.0
Orlando	1.5	1.1	-0.4	0.8	0.8	0.0
Phoenix	2.4	1.8	-0.6	1.3	1.3	0.0
Charleston	9.1	7.3	-1.7	5.1	5.1	0.0
Charlotte	41.4	33.7	-7.7	23.3	23.3	0.0
Oklahoma City	60.8	52.1	-8.7	35.3	35.3	0.0
Las Vegas	25.1	21.2	-3.9	14.5	14.5	0.0
Baltimore	54.5	43.1	-11.4	39.2	39.2	0.0
Kansas City	67.6	55.0	-12.5	49.1	49.1	0.0
Chicago	77.6	62.5	-15.1	62.6	62.6	0.0
Denver	57.4	48.2	-9.3	48.4	48.4	0.0
Minneapolis	95.0	76.0	-19.1	73.1	73.1	0.0
Billings	76.9	62.5	-14.4	60.0	60.0	0.0
Fargo	117.1	92.0	-25.1	88.3	88.3	0.0
Fairbanks	175.5	143.0	-32.5	134.5	134.5	0.0

Table A-4: HE Home heating energy consumption and differences between IECC and Standard 301 for all homes.

HE Homes Heating Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	0.3	0.2	-0.1	0.2	0.2	0.0
Houston	6.0	4.8	-1.2	4.0	4.0	0.0
Orlando	1.5	1.1	-0.4	0.9	0.9	0.0
Phoenix	2.4	1.8	-0.6	1.6	1.6	0.0
Charleston	9.1	7.3	-1.7	5.9	5.9	0.0
Charlotte	41.4	33.8	-7.7	26.0	26.0	0.0
Oklahoma City	60.9	52.2	-8.7	38.0	38.0	0.0
Las Vegas	25.2	21.3	-3.9	15.9	15.9	0.0
Baltimore	54.7	43.2	-11.4	38.5	38.5	0.0
Kansas City	67.7	55.1	-12.5	46.1	46.1	0.0
Chicago	77.8	62.7	-15.1	53.4	53.4	0.0
Denver	57.6	48.3	-9.3	40.2	40.2	0.0
Minneapolis	95.2	76.1	-19.1	64.5	64.5	0.0
Billings	77.0	62.7	-14.4	52.0	52.0	0.0
Fargo	117.2	92.1	-25.1	73.9	73.9	0.0
Fairbanks	175.7	143.2	-32.5	109.8	109.8	0.0

Table A-5: PV Home cooling energy consumption and differences between IECC and Standard 301 for all homes.

PV Homes Cooling Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	22.3	20.7	-1.6	14.1	14.1	0.0
Houston	14.1	13.1	-1.0	8.2	8.2	0.0
Orlando	14.5	13.5	-1.0	8.5	8.5	0.0
Phoenix	26.0	24.7	-1.3	15.0	15.0	0.0
Charleston	13.6	13.0	-0.7	6.7	6.7	0.0
Charlotte	10.1	9.8	-0.3	4.6	4.6	0.0
Oklahoma City	12.5	11.9	-0.5	5.8	5.8	0.0
Las Vegas	19.0	18.4	-0.6	9.4	9.4	0.0
Baltimore	7.3	7.1	-0.2	3.8	3.8	0.0
Kansas City	8.1	7.9	-0.3	4.1	4.1	0.0
Chicago	3.3	3.2	-0.1	1.4	1.4	0.0
Denver	2.9	2.9	0.0	1.0	1.0	0.0
Minneapolis	2.6	2.5	-0.1	1.0	1.0	0.0
Billings	1.9	1.9	0.0	0.7	0.7	0.0
Fargo	1.7	1.7	0.0	0.4	0.4	0.0
Fairbanks	0.2	0.2	0.0	0.0	0.0	0.0

Table A-6: HE Home cooling energy consumption and differences between IECC and Standard 301 for all homes.

HE Homes Cooling Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	22.2	20.7	-1.6	11.9	11.9	0.0
Houston	14.0	13.1	-0.9	6.8	6.8	0.0
Orlando	14.5	13.5	-1.0	7.3	7.3	0.0
Phoenix	26.0	24.6	-1.3	13.7	13.7	0.0
Charleston	13.5	12.9	-0.6	6.3	6.3	0.0
Charlotte	10.0	9.7	-0.3	4.5	4.5	0.0
Oklahoma City	12.4	11.9	-0.5	5.7	5.7	0.0
Las Vegas	18.9	18.3	-0.6	9.7	9.7	0.0
Baltimore	7.2	7.0	-0.2	3.7	3.7	0.0
Kansas City	8.1	7.8	-0.3	4.3	4.3	0.0
Chicago	3.2	3.1	-0.1	1.3	1.3	0.0
Denver	2.9	2.9	0.0	1.0	1.0	0.0
Minneapolis	2.6	2.5	-0.1	0.9	0.9	0.0
Billings	1.9	1.9	0.0	0.7	0.7	0.0
Fargo	1.7	1.7	0.0	0.4	0.4	0.0
Fairbanks	0.1	0.2	0.0	0.0	0.0	0.0

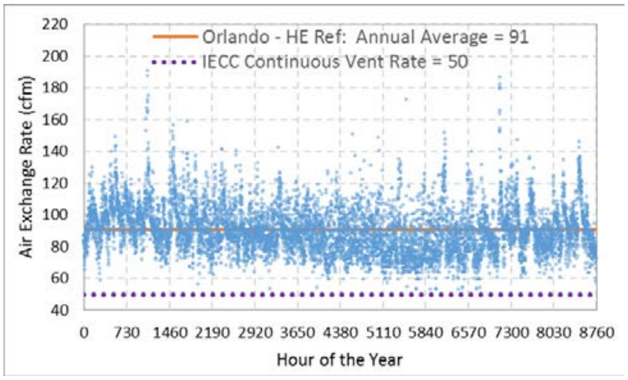
Table A-7: PV Home total energy consumption and differences between IECC and Standard 301 for all homes.

PV Homes Total Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	54.2	52.5	-1.7	39.1	39.1	0.0
Houston	53.4	51.2	-2.2	38.5	38.5	0.0
Orlando	48.7	47.3	-1.4	35.1	35.1	0.0
Phoenix	60.2	58.3	-1.9	41.3	41.3	0.0
Charleston	57.0	54.6	-2.4	39.2	39.2	0.0
Charlotte	93.6	85.7	-7.9	62.1	62.1	0.0
Oklahoma City	115.7	106.5	-9.2	75.5	75.5	0.0
Las Vegas	83.7	79.2	-4.5	55.3	55.3	0.0
Baltimore	105.7	94.1	-11.6	78.7	78.7	0.0
Kansas City	120.3	107.5	-12.8	89.5	89.5	0.0
Chicago	125.1	109.9	-15.2	101.0	101.0	0.0
Denver	104.1	94.9	-9.3	86.0	86.0	0.0
Minneapolis	142.9	123.8	-19.1	111.8	111.8	0.0
Billings	123.5	109.1	-14.4	97.7	97.7	0.0
Fargo	165.3	140.1	-25.2	127.9	127.9	0.0
Fairbanks	225.5	193.0	-32.5	177.3	177.3	0.0

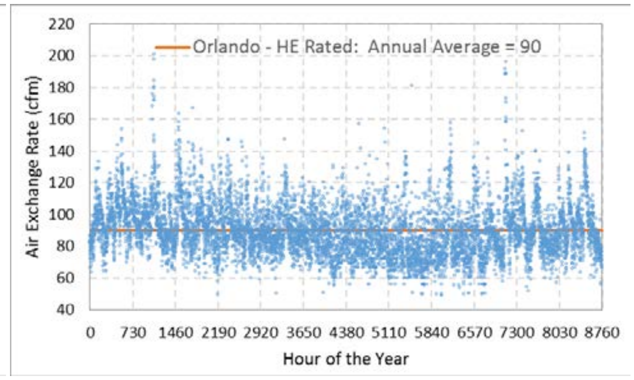
Table A-8: HE Home total energy consumption and differences between IECC and Standard 301 for all homes.

HE Homes Total Energy	Reference Homes (MBtu)			Rated Homes (MBtu)		
	301 HERS	2018 IECC	Delta MBtu	301 HERS	2018 IECC	Delta MBtu
Miami	54.1	52.5	-1.7	31.9	31.9	0.0
Houston	53.3	51.2	-2.2	31.4	31.4	0.0
Orlando	48.7	47.3	-1.4	28.6	28.6	0.0
Phoenix	60.1	58.3	-1.9	35.2	35.2	0.0
Charleston	56.7	54.3	-2.4	33.2	33.2	0.0
Charlotte	93.1	85.2	-7.9	57.4	57.4	0.0
Oklahoma City	115.2	105.9	-9.2	70.8	70.8	0.0
Las Vegas	83.0	78.5	-4.5	50.6	50.6	0.0
Baltimore	105.2	93.6	-11.6	70.1	70.1	0.0
Kansas City	119.7	106.9	-12.8	78.8	78.8	0.0
Chicago	124.6	109.4	-15.2	84.1	84.1	0.0
Denver	103.6	94.4	-9.3	69.6	69.6	0.0
Minneapolis	142.5	123.4	-19.1	95.7	95.7	0.0
Billings	123.1	108.8	-14.4	82.5	82.5	0.0
Fargo	164.9	139.7	-25.2	105.7	105.7	0.0
Fairbanks	225.2	192.7	-32.5	144.2	144.2	0.0

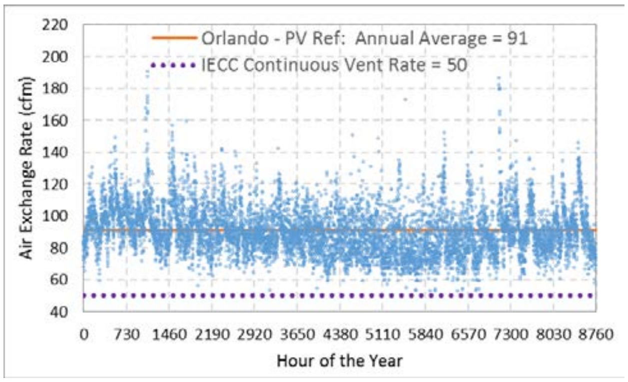
Representative Hourly Air Exchange Rate Charts



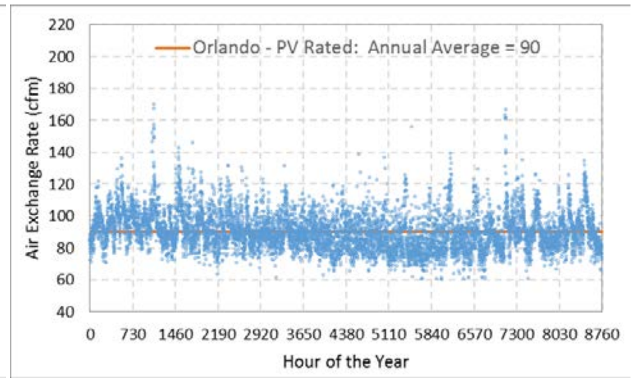
Orlando HE Reference Home Total Air Exchange



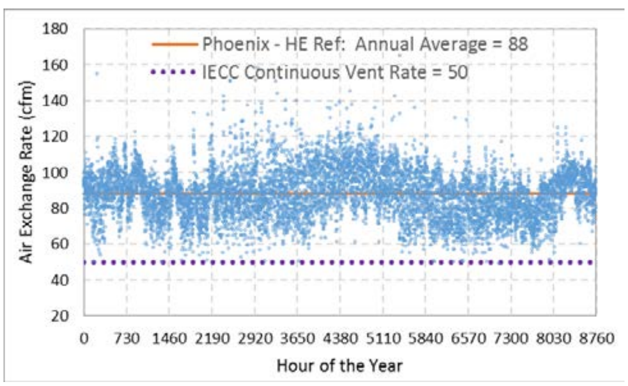
Orlando HE Rated Home Total Air Exchange



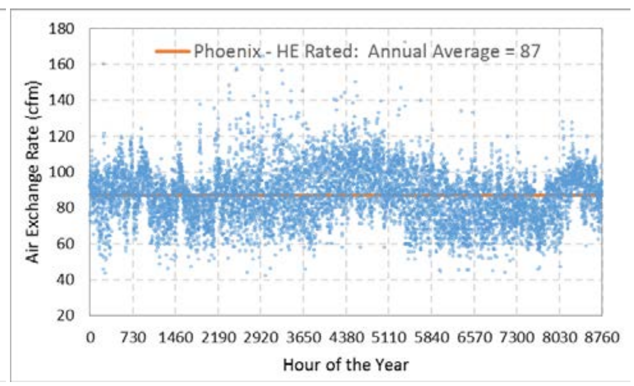
Orlando PV Reference Home Total Air Exchange



Orlando PV Rated Home Total Air Exchange



Phoenix HE Reference Home Total Air Exchange



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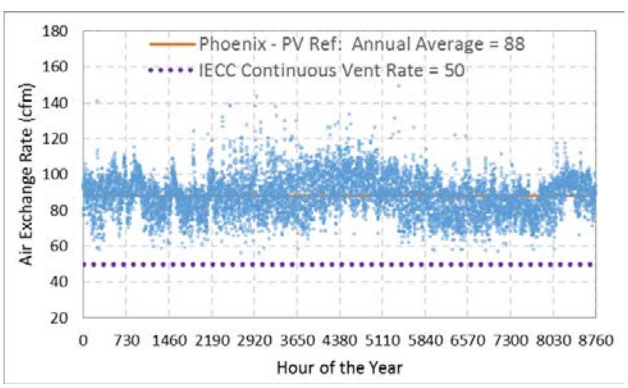

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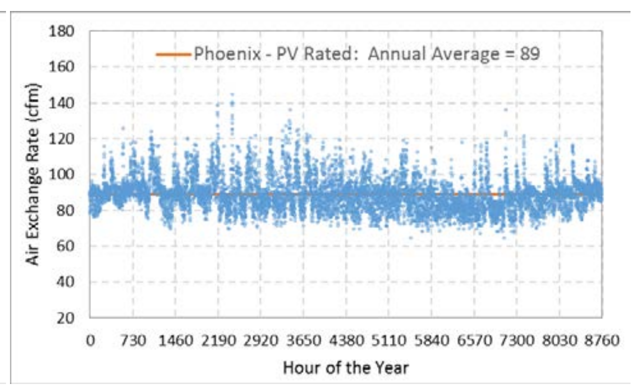
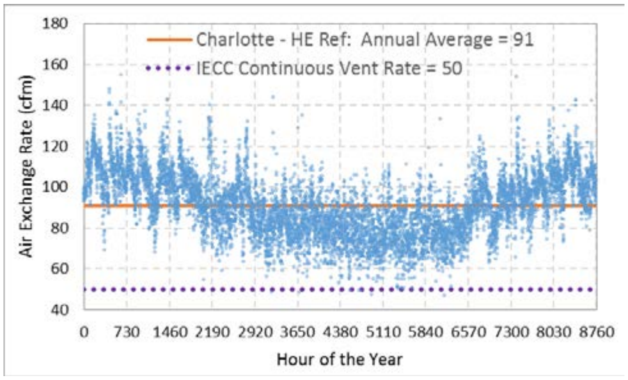
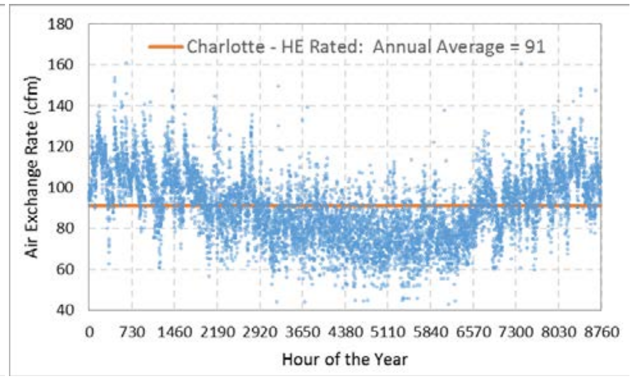


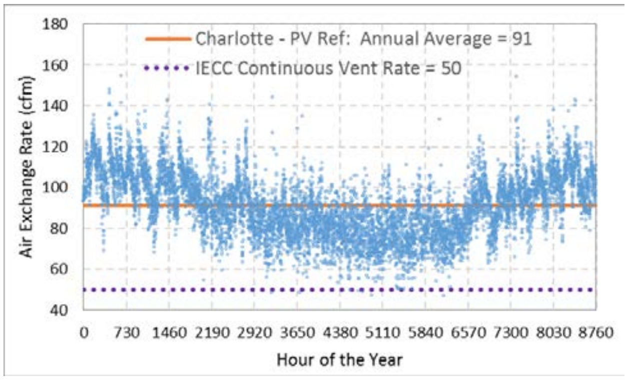
Phoenix PV Rated Home Total Air Exchange



Charlotte HE Reference Home Total Air Exchange



Charlotte HE Rated Home Total Air Exchange



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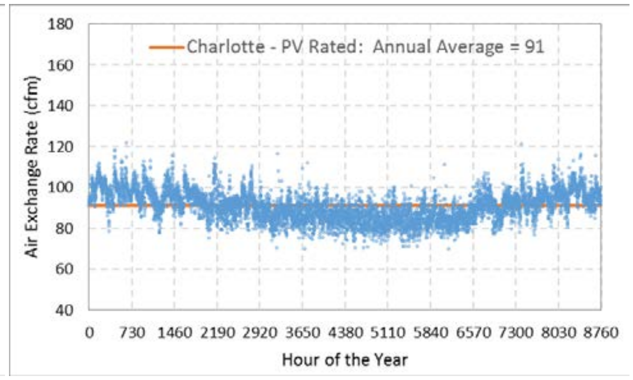
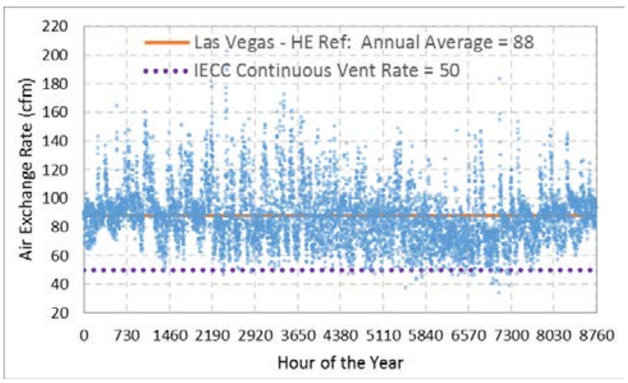
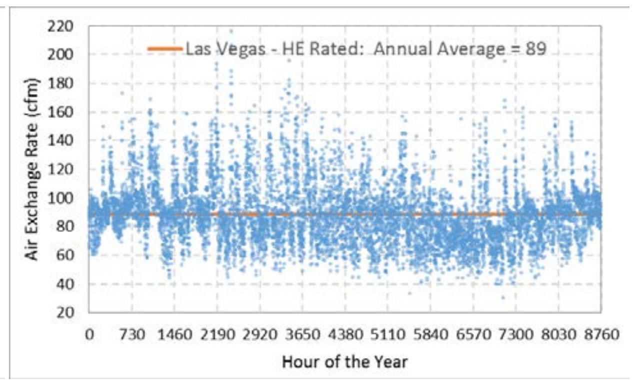


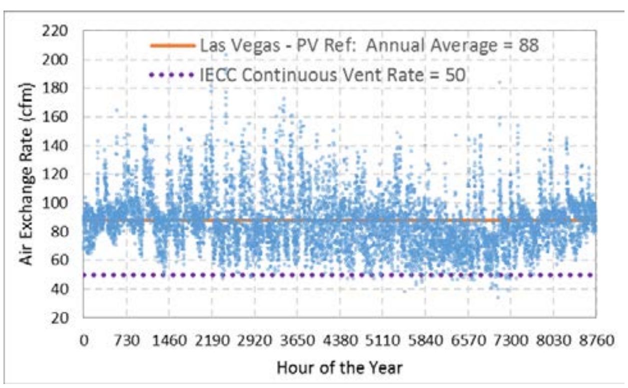
Charlotte PV Rated Home Total Air Exchange



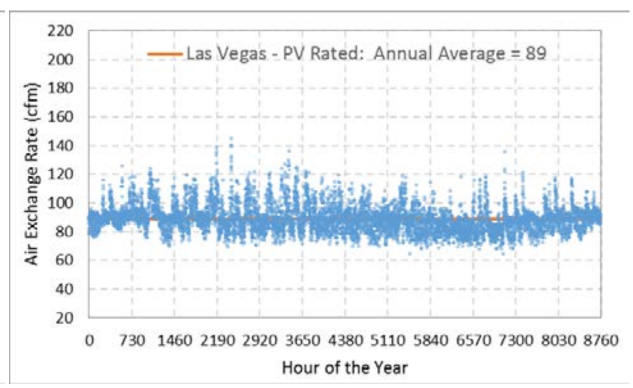
Las Vegas HE Reference Home Total Air Exchange



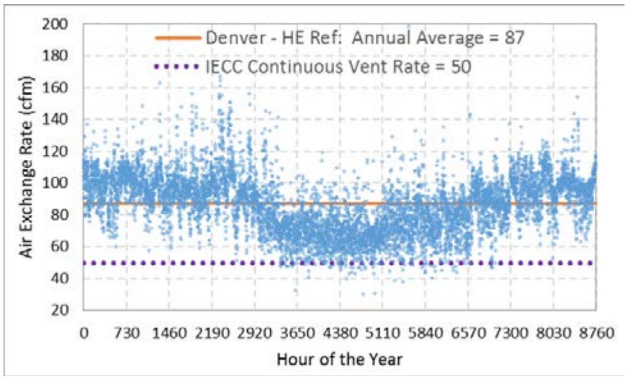
Las Vegas HE Rated Home Total Air Exchange



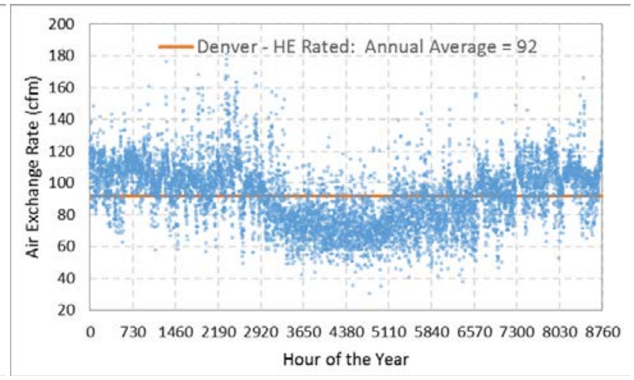
Las Vegas PV Reference Home Total Air Exchange



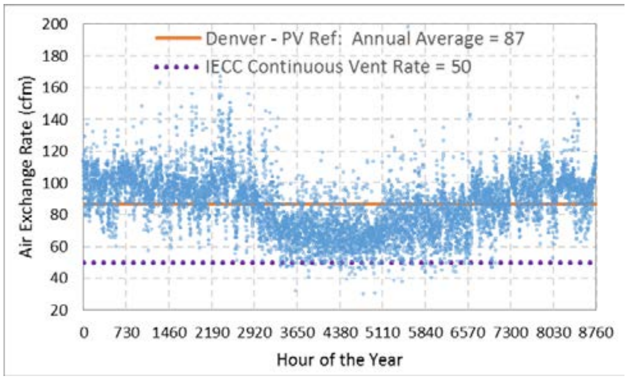
Las Vegas PV Rated Home Total Air Exchange



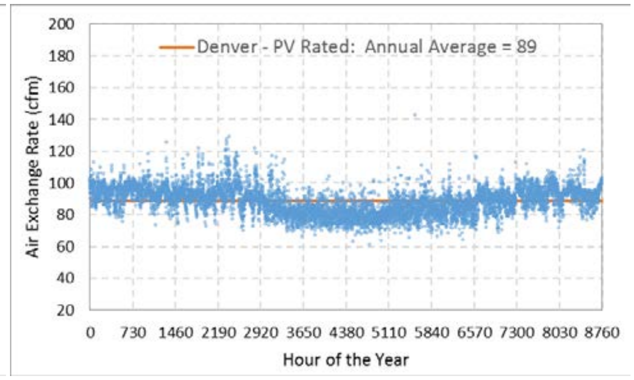
Denver HE Reference Home Total Air Exchange



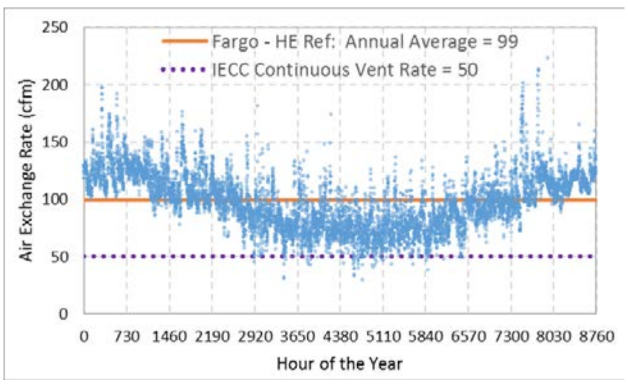
Denver HE Rated Home Total Air Exchange



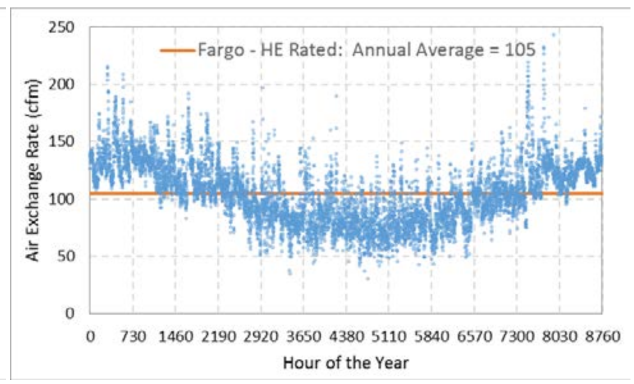
Denver PV Reference Home Total Air Exchange



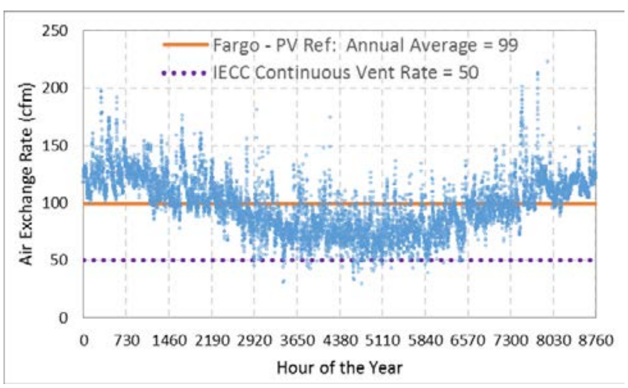
Denver Vegas PV Rated Home Total Air Exchange



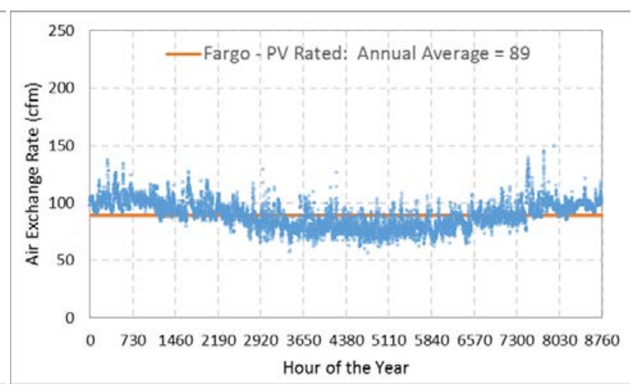
Fargo HE Reference Home Total Air Exchange



Fargo HE Rated Home Total Air Exchange



Fargo PV Reference Home Total Air Exchange



Fargo Vegas PV Rated Home Total Air Exchange