### COMPARING THE PERFORMANCE OF A 2009 IECC CODE- COMPLIANT HOUSE USING CODE-COMPLIANT RESIDENTIAL SIMULATION PROGRAMS

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#### ABSTRACT

The Residential Energy Services Network (RESNET) is an independent, non-profit organization that helps homeowners reduce energy costs by providing energy efficiency strategies. RESNET performs certification of code-compliance software using a test suite (RESNET 2007). Acceptance variations in the RESNET tests include a provision of minimum and maximum limits of variation on a case-bycase basis or a sensitivity basis. Results are provided for either heating or cooling loads or heating and cooling energy consumption (RESNET 2007). However, significant differences exist in the results obtained from these software programs on performing compliance with the performance path specified in the International Energy Conservation Code (IECC).

This paper is a continuation of an earlier attempt to explore these differences and find out the cause of such discrepancies (Liu et al., 2010). This paper also determines a bandwidth within which variation in results from the different software programs that can be deemed to be acceptable. The paper provides a comparison of four codecompliant software, three of which are RESNET certified. The comparison is performed for three climate zones in Texas. For most cases of the comparison, the results from the three RESNET certified software are within 5% of each other. However, variation in results from the three RESNET certified software programs exceeds 5% in certain cases of ceiling R-values in all climate zones and in certain cases of window-towall area ratios in Climate Zone-4.

#### **INTRODUCTION**

Previously, a paper by Liu et al. (2010) compared the results from three RESNET certified software programs used for the State of Texas. The previous paper provided a comparison of the 2001 IECC compliant house. The study concluded that significant differences can exist between the selected tools due to differences in interpreting the 2001 IECC, auto-generation of inputs and other assumptions.

This paper summarizes the information provided in a new report that compares the performance of a 2009 IECC compliant house simulated using four code-compliance software programs (Mukhopadhyay et al. 2012). The performance path alternative<sup>1</sup> provided in the 2009 IECC is used by the software programs selected for this analysis (ICC 2009). The performance path analysis provided in the 2009 IECC requires that a building energy simulation be performed to determine whether the annual energy cost of the proposed residence to be less than the annual energy cost of the standard reference design home<sup>2,3</sup>.

The four software programs selected are as follows:

- IC3 (version 3.12.1)
- REM/Rate (version 13.0)
- REScheck (version 4.4.3)<sup>4</sup>
- EnergyGauge (version 2.8.05)<sup>5</sup>

As of May 2013, three of the software programs selected for this analysis, (i.e. IC3, REMRate and EnergyGauge) are certified by RESNET to provide compliance with the 2006 IECC (RESNET 2007). However, currently RESNET does not provide certification for the 2009 IECC compliant software programs. As part of its

<sup>&</sup>lt;sup>1</sup> Section 405, Simulated Performance Alternative, 2009 IECC (ICC 2009).

 <sup>&</sup>lt;sup>2</sup> 2009 IECC, Section 405.3 Performance-based compliance.
 <sup>3</sup> The 2009 IECC also provides an exception to Section

<sup>405.3,</sup> which allows the use of source energy to be substituted for energy costs. The source energy multipliers of

<sup>3.16</sup> and 1.1 are recommended for electricity and natural gas usage respectively.

<sup>&</sup>lt;sup>4</sup> REScheck provides a limited performance approach for compliance with the IECC (Bartlett et al. 2012).

<sup>&</sup>lt;sup>5</sup> This version of EnergyGauge does not support compliance with the 2009 IECC. Therefore, a 2009 IECC compliant

responsibilities, RESNET performs certification of code-compliance software. The verification is provided in form of a test suite provided by RESNET. Acceptance variations in the tests include a provision of minimum and maximum limits of variation in on a case-by-case basis or a sensitivity basis. Results are provided for either heating or cooling loads or corresponding energy consumption (RESNET 2007).

Although these programs have been extensively used to provide compliance, significant differences have known to occur in the results of the three software programs. It is observed that even the smallest of difference can cause the house to pass the code when using one software program and fail when using another software program.

Therefore, the purpose of this paper is to provide a look at some of the differences in the codecompliance results using 2009 IECC for compliance. This is done by means of a sensitivity analysis that is performed to identify the possible reasons for the differences.

# DESCRIPTION OF THE SIMULATION SUITE

In order to compare the performance of the software programs, a sensitivity analysis was conducted. For this purpose, several parameters were selected that were common to the four selected software programs. The analysis proceeded to vary each parameter individually and document the corresponding percentage difference above / below the 2009 IECC code-compliant base-case provided by each of the four simulation programs.

Three cities were selected by this analysis to represent the three climate zones in the State of Texas. These include: Houston, representing Climate Zone 2A; Dallas, representing Climate Zone 3A; and Amarillo, representing Climate Zone 4B. The Climate Zones and the location of cities selected to represent these zones are provided in Figure 1. The four software programs described in the previous section will be referenced to as: Software 1, Software 2, Software 3 and Software 4, which does not necessarily correspond to the order presented in the section above.

The proposed base-case design house used for this analysis was a 2009 IECC code-compliant<sup>6</sup> house. Details of the house are provided in the next section.



Figure 1: Texas Climate Zones

Parameters used for the sensitivity analysis include the following<sup>7</sup>:

- House size with fixed window area of 60 ft<sup>2</sup>: 1,000 ft<sup>2</sup>, 2,500 ft<sup>2</sup>, 3,000 ft<sup>2</sup>, 4,000 ft<sup>2</sup> and 5,000 ft<sup>2</sup>.
- House size with fixed window-to-wall area ratio of 15%: 1,000 ft<sup>2</sup>, 2,500 ft<sup>2</sup>, 3,000 ft<sup>2</sup>, 4,000 ft<sup>2</sup> and 5,000 ft<sup>2</sup>.
- Window to wall area ratio: 10%, 20%, 30%, 40% and 50%.
- Wall insulation (exterior): R-0 (None), R-3, R-6 and R-9.
- Ceiling insulation: R-30, R-40, R-50 and R-60.
- Window SHGC: 0.2, 0.3, 0.4 and 0.5.
- Window U-value: 0.25, 0.45, 0.65 and 0.75.
- Slab insulation (For Climate Zone 4B): R-0 (Un-insulated slab), R-5, R-10, and R-15.

#### DESCRIPTION OF THE PROPOSED BASE-CASE HOUSE

Standard Reference House was manually created for this analysis.

<sup>&</sup>lt;sup>6</sup> Table 405.5.2(1), 2009 IECC, Specifications for the Standard Reference and Proposed Designs.

<sup>&</sup>lt;sup>7</sup> It should be noted that mechanical equipment trade-offs are not allowed in the performance path compliance in the 2009 IECC. Hence variations in equipment specifications have not been considered for analysis.

The base-case design proposed house implemented for this analysis was a 2009 IECC compliant<sup>8</sup> single-family, single-story house with three bedrooms and a conditioned floor area of  $2,500 \text{ ft}^2$ . The front of the house faced south. The base-case model had a slab-on-grade floor construction. The window-to-wall area ratio (WWAR) was set at 15%<sup>9</sup>. No exterior shading was implemented in the base-case model <sup>10</sup>. Specifications for the building envelope such as wall insulation, ceiling insulation, slab insulation, glazing details, and specifications for opaque doors were carefully matched to the provisions in the 2009 IECC (ICC 2009)<sup>11,12,13</sup>. In addition, space conditions, infiltration rates, internal heat gains and the thermostat settings used in the basecase model were also matched to the provisions in the 2009 IECC (ICC 2009)14.

Space conditioning equipment used electricity for space cooling, natural gas space heating and natural gas domestic hot water heating. The efficiencies of mechanical systems in the base-case house were in compliance with the specifications of the 2009 IECC which use 2006 NAECA <sup>15</sup> requirements. The efficiencies included SEER 13 for the air conditioner, an AFUE of 0.78 for the gas furnace, and an Efficiency Factor of 0.594<sup>16</sup> for the domestic hot water heater, which has a tank volume of 40 gallons (Hendron 2008).

The cooling system for the proposed house were sized using 500 ft<sup>2</sup> / ton<sup>17,18</sup>. For the reference home, the cooling system were sized at 500 ft<sup>2</sup> / ton for Software 1 and Software 3, and was autosized in Software  $2^{19}$ . Finally, the sizing criteria in Software 4 was not provided and hence was not documented in this analysis. The sizing for the Reference house used in the three software

programs is provided in Figure 2 and Figure 3 of this paper.

When considering the size of cooling systems, for all house sizes in Climate Zone 2 and Climate Zone 3 and most house sizes in Climate Zone 4, the size of the cooling system for the Reference house is similar in the three Software Programs. However, for larger house sizes in Climate zone 4 (i.e. 4000  $ft^2$  and 5000  $ft^2$ ), the cooling system size is considerably smaller than the cooling system sized using the 500 ft<sup>2</sup>/ton rule of thumb in Software 1 and Software 3. It is also noted that for smaller house sizes (i.e.  $1000 \text{ft}^2$ ), the cooling system in the Reference house of Software 2 is consistently bigger than the corresponding system sized using 500 ft<sup>2</sup>/ton in Software 1and Software 3. For heating system sizes, the system sizing for the Reference house in Software 2 are consistently bigger than the corresponding systems sized using the 500ft<sup>2</sup>/ton rule of thumb in Software 1 and Software 3. The difference in system sizing becomes more prominent on going from Climate Zone 2 to 4.

DHW usage for the base-case house used the specifications of the 2009 IECC<sup>20</sup>. The ducts were located in the attic, and the specifications for duct leakage and the duct insulation were assumed to be in compliance with the 2009 IECC. The consolidated input for the proposed house in the four software programs is provided in Table 1.

<sup>&</sup>lt;sup>8</sup> Table 405.5.2(1), 2009 IECC, Specifications for the

Standard Reference and Proposed Designs.

<sup>&</sup>lt;sup>9</sup> Table 405.5.2(1), 2009 IECC, Glazing.

<sup>&</sup>lt;sup>10</sup> Table 405.5.2(1), 2009 IECC, Glazing.

<sup>&</sup>lt;sup>11</sup> Table 405.5.2(1), 2009 IECC, Above-grade walls,

Ceilings, Foundations, Doors, Glazing.

<sup>&</sup>lt;sup>12</sup> Table 402.1.1, 2009 IECC, Insulation and Fenestration Requirements by Component.

<sup>&</sup>lt;sup>13</sup> Table 402.1.3, 2009 IECC, Equivalent U-Factors.

<sup>&</sup>lt;sup>14</sup> Table 405.5.2(1), 2009 IECC, Air exchange rate, Internal gains, Thermostat.

<sup>&</sup>lt;sup>15</sup> National Appliance Energy Conservation Act of 1987 with 2006 amendments.

<sup>&</sup>lt;sup>16</sup> This efficiency was calculated from the equation provided in the Table 504.2, 2009 IECC Minimum Performance of

Water Heating Equipment, 40 Gallon Gas-fired Storage water heaters.

<sup>&</sup>lt;sup>17</sup> This assumption was based on standard practice for HVAC contractors in Texas.

<sup>&</sup>lt;sup>18</sup> Corresponding heating system was sized at 500 ft2/12000Btu/hr.

<sup>&</sup>lt;sup>19</sup> For the case of ducts in attic described in this paper, the sizing results obtained from Software 2 are similar to those determined in Software 1 and Software 3. However, this is not the case when ducts are positioned in conditioned space. In this case sizing results from Software 3 are much smaller which in turn impact the percentage above code values (Mukhopadhyay et al. 2012).

<sup>&</sup>lt;sup>20</sup> Table 405.5.2(1), 2009 IECC, Service water heating.



Figure 2: Cooling System Sizing for the Standard Reference Home Provided by the Three Software Programs for the Three Climate Zones in Texas



Figure 3: Heating System Sizing for the Standard Reference Home Provided by the Three Software Programs for the Three Climate Zones in Texas

IC3 (3.12.1)		REM / Rate (13.00)		REScheck (4.4.3)		EnergyGauge (2.8.05)	
PROJECT							
# Bedrooms	3	# Bedrooms	3			# Bedrooms	3
# Stories	1	# Stories	1			# Stories	1
Building Azumith	South					# Bathrooms	2
Conditioned Area (sqft)	2,500	Conditioned Area (sqft)	2,500	Conditioned Area (sqft)	2,500	Conditioned Area (sqft)	2,500
Average Wall Height (It)	8	Condition of Websers (confi)	20.000			Average Wall Height (It)	8
	Single family	Conditioned volume (cuit)	20,000 Single family		Single family	Conditioned volume (cuit)	20,000
Housing type	detached	Housing type	detached	Housing type	detached	Housing type	Single family
CLIMATE	detactied	Housing type	detuened	riousing type	detached		
CLIMATE	CZ 2A Homio		Houston		Houston		CZ 24 Houston
Location	CZ 2A - Harrant	Location	Dallas/Fort Worth	Location	Dallas	Location	CZ 2A - Houston
Location	CZ 4B - Potter	Location	Amarillo	Location	Amarillo	Location	CZ 4B - Amarillo
Weather File	TMY2					Weather File	TMY2
	CZ 2A - 1500		CZ 2A - 1548				CZ 2A - 1434
HDD	CZ 3A - 2000	HDD	CZ 3A - 2420			HDD	CZ 3A - 2420
	CZ 4B - 4000		CZ 4B - 4240				CZ 4B - 4183
FLOORS							
Tues	Slah on anda				Slab-on-grade		Slab-on-grade edge
Type	Siab-on-grade	Туре	Slab-on-grade	Туре	Unheated	Туре	insulation
	C7.2A P.0		C7 24 R 0		C7.24 P.0		CZ 2A - R-0
R-value.	CZ 3A - R-0	R-value	CZ 3A - R-0	R-value	CZ 3A - R-0	R-value	CZ 3A - R-0
	CZ 4B - R-10.2ft		CZ 4B - R-10.2ft		CZ 4B - R-10.2ft		CZ 4B - R-10, Ext.
	CE 45 K 10, 2K		CE 45 R 10, 2R		CE 45 R 10, 2R		insulation
Floor Finish	20% tile,	Floor Covering	Carpet			Floor Finish	20% tile,
	80% Carpet						80% Carpet
Area (sqft)	2,500	Area (sqft)	2,500	Eull Darimator (6)	200	Area (sqft) Derivator (ft)	2,500
reimeter (it)	200	Dapth balow Grada (6)	200	rud Perimeter (It)	200	reimeter (it)	200
		Total Exposed Parimeter (ft)	200				
		On Grade Exposed Perimeter (ft)	200				
ROOF		on Gude Esposed Permeter (it)	200				
Configuration	Gable					Configuration	Gable
Attic Type	Full attic					Attic Type	Full Attic
Roofing Material	Asphalt shingles					Roofing Material	Comp. Shingles
						Conditioned Ceiling Footprint Area	2.500 saft
Roof Emissivity	0.9	-					
Absorptance	0.75					Absorptance	0.75
Radiant Barrier	No	Radiant Barrier	No			Radiant Barrier	No
Roof Insulation	R-0					Roof Deck Insulation	R-0
						Roof Framing Fraction	0.1
		Attic Exterior (sqft)	2,500				
Slope (Degrees)	23					Slope in inches	5.1/12
		Exterior Color	Medium			Roof Color	Medium
		Clay or Concrete Roofing	No				
A stip Ventilation	0.0022	Sub-Tile Ventilation	NO			Attia Vantilation	0.0022
Attic ventilation	0.0033					Attic ventilation	0.0033
CEILING					Elet seiling or		Under ettie
Туре	Under attic	Type	Blown, attic	Type	Scissor Truss	Type	Under attic
	CZ.2A - B-27.8	1990	CZ 2A - B-27.8	1990	CZ 2A - R-30	Type	CZ.2A - R-25.75
R-value	CZ 3A - R-27.8	R-value	CZ 3A - R-27.8	R-value	CZ 3A - R-30	R-value	CZ 3A - R-25.75
	CZ 4B - R-32.5		CZ 4B - R-32.5		CZ 4B - R-38		CZ 4B - R-30
Framing Factor	7%	Framing Factor	7%			Framing Factor	7%
Area	2,500	Area	2,500	Area	2,500	Area	2,500
	CZ 2A - 0.035		CZ 2A - 0.035		CZ 2A - 0.035		CZ 2A - 0.035
Overall U-value	CZ 3A - 0.035	Overall U-value	CZ 3A - 0.035	Overall U-value	CZ 3A - 0.035	Overall U-value	CZ 3A - 0.035
	CZ 4B - 0.030		CZ 4B - 0.030		CZ 4B - 0.030		CZ 4B - 0.030
WALLS							
Type	Frame wood	Type	Frame wood	Type	Frame wood	Туре	Frame wood
->1-	. mine wood	-21-	Thank wood	-71-	16" O.C.		Think wood
	CZ 2A - R-11.8		CZ 2A - R-11.8		CZ 2A - R-13		CZ 2A - R-14.5
Cavity Insulation	CZ 3A - R-11.8	Cavity Insulation	CZ 3A - R-11.8	Cavity Insulation	CZ 3A - R-13	Cavity Insulation	CZ 3A - K-14.5
	CZ 4B - K-11.8		CZ 4D - K-11.8		CZ 4D - K-13		CZ 4D - R-14.3
Querall II value	CZ 2A - 0.082	Fourivalant II value	CZ 2A - 0.082	Fauiyalant II yalua	CZ 2A - 0.082	Overall II value	CZ 2A - 0.082
Overall O-value	CZ 4B - 0.082	rajaivaient o-vaitte	CZ 3A - 0.082	aquivalent O-value	CZ 3A - 0.082	Overall O-value	CZ 4B - 0.082
Empire Exection	250/	Francis a Francis	22.40-0.002		CZ. 4D - 0.062	Esopia a Esstar	250/
Sheathing R-value	25%	rianing Pactor	23%			Sheathing R-value	25%
Solar Absorptance	0.75					Solar Absomtance	0.75
	0.75	Gross Area (soft)	400 x 4	Gross Area (sqft)	400 x 4	Gross Area (sqft)	400 x 4
Exterior Finish	Brick	Exterior Finish	Brick		100 4 1		
		Exterior Color	Light				
			Batwaan				
		Location	conditioned one			A discent To	Exterior
		Location	and ambient			Aujacent 10	EMERIOF
			and ampient				
DOORS							
Orientation	North, south	Orientation	North, south	Orientation	North, south	Orientation	North, south
Area (sqft)	20.01	Opaque Area (sqft)	20.01	Opaque Area (sqft)	20.01	Area (sqft)	20.01
	CZ 2A - 0.65		CZ 2A - 0.65		CZ 2A - 0.65		CZ 2A - 0.65
U-value (Btu/hr-sqft-F)	CZ 3A - 0.5	U-value (Btu/hr-sqft-F)	CZ 3A - 0.5	U-value (Btu/hr-sqft-F)	CZ 3A - 0.5	U-value (Btu/hr-sqft-F)	CZ 3A - 0.5
	CZ 4B - 0.35		CZ 4B - 0.35		CZ 4B - 0.35		CZ 4B - 0.35
	1	R-value	1.54				
L		Storm Door	No			I L	

# Table 1: Input for the Proposed Base-Case House in the Four Software Programs to Comply with the 2009 IECC

Notes:

- Cells marked in yellow indicate information specific to the Climate Zones selected by this analysis.

In REM/Rate, the exterior walls are specified using the 'Path Layer' option provided in the software program. This option allows
the user to manually input R-values of different components of the exterior wall, which includes separate input for cavity and
framing components of the exterior wall.

NUMBER         Image: Sample state         I	IC3 (3.12.1)		REM / Rate (13.00)		REScheck (4.4.3)		EnergyGauge (2.8.05)	
Cale of C2 h. 68 C2 h.	WINDOWS & SHADING							
UnderCZA A.6UnderCZA A.6UnderCZA A.6UnderCZA A.6UnderCZA A.6CZA A.6		CZ 2A - 0.65		CZ 2A - 0.65		CZ 2A - 0.65		CZ 2A - 0.65
C24 a.03 $  C24 a.03$ $  C24 a.04 C  C24 a.04 C$	U-value	CZ 3A - 0.5	U-value	CZ 3A - 0.5	U-value	CZ 3A - 0.5	U-value	CZ 3A - 0.5
SuchC2A-03 C2A-03 C2A-04 C2A		CZ 4B - 0.35		CZ 4B - 0.35		CZ 4B - 0.35		CZ 4B - 0.35
SINCC/2 A)-34 C/2 B-44 (20)SINCC/2 A-43 (2) C/2 B-44 (20)SINCC/2 B-44 (20) C/2 B-44 (20)SINCC/2 B-44 (20) C/2 B-44 (20)max TypeNameNameC/2 B-44 (20)C/2 B-44 (20)Name TypeName Type <t< td=""><td></td><td>CZ 2A - 0.3</td><td></td><td>CZ 2A - 0.3</td><td></td><td>CZ 2A - 0.3</td><td></td><td>CZ 2A - 0.3</td></t<>		CZ 2A - 0.3		CZ 2A - 0.3		CZ 2A - 0.3		CZ 2A - 0.3
controlCZ8-04.080controlCZ8-04.080controlCZ8-04.080CZ8-0	SHOC	CZ 3A - 0.3	SHGC	CZ 3A - 0.3	SHGC	CZ 3A - 0.3	SHGC	CZ 3A - 0.3
No. figus1No. figusNo. figus1Dering TypeMightPipel area offNo. figusNo. figus <td< td=""><td></td><td>CZ 4B - 0.4 (NR)</td><td></td><td>CZ 4B - 0.4 (NR)</td><td></td><td>CZ 4B - 0.4 (NR)</td><td></td><td>CZ 4B - 0.4 (NR)</td></td<>		CZ 4B - 0.4 (NR)		CZ 4B - 0.4 (NR)		CZ 4B - 0.4 (NR)		CZ 4B - 0.4 (NR)
TransName	No. of Panes	1					No. of Panes	1
Wathor Acc oughØ. 3Wathor Acc (u.g.)Ø. 1Ø. 1Wathor Acc (u.g.)Ø. 4Ø. 4Chentain on one one one one one one one one one	Frame Type	Vinyl					Frame Type	Vinyl
GenutionFight at controlBeglatt control <td>Window Area (sqft)</td> <td>60 x 4</td>	Window Area (sqft)	60 x 4	Window Area (sqft)	60 x 4	Window Area (sqft)	60 x 4	Window Area (sqft)	60 x 4
orealing Depth (i)         orealin	Orientation	Equal area on all	Orientation	Equal area on all	Orientation	Equal area on all	Orientation	Equal area on all
Oriental (print)         O         District Window         O           Interior Stadie Water         O.S.         District Window         O           Interior Stadie State Water         O.S.         District Window         District Window <thdistrict th="" window<=""> <thdistrict td="" th<="" window<=""><td>Orestern Death (6)</td><td>orientations</td><td>Out to a Darit (ft)</td><td>orientations</td><td></td><td>orientations</td><td>Out the Durch (6)</td><td>orientations</td></thdistrict></thdistrict>	Orestern Death (6)	orientations	Out to a Darit (ft)	orientations		orientations	Out the Durch (6)	orientations
Import Shade Summer         Definition of Window (D)         0         Import Shade Summer         0           Interior Shade Summer         0.7         Aligeen Shade Summer         0.7         Interior Shade Summer         0.8           Interior Shade Summer         0.7         Aligeen Shade Summer         0.7         Interior Shade Summer         0.8           Interior Shade Summer         0.8         Aligeen Shade Summer         0.8         Interior Shade Summer         0.8           NUMLIANT SUMMER         Algeen Shade Summer         None         None <t< td=""><td>Ovemang Deptn (it)</td><td>0</td><td>To Top of Window</td><td>0</td><td></td><td></td><td>To Top of Window</td><td>0</td></t<>	Ovemang Deptn (it)	0	To Top of Window	0			To Top of Window	0
Interior Sulta Winter         0.55         Interior Sulta Summer         0.75           Levins Sulta Summer         0.75         Algeent Sulta Summer         0.75           Levins Sulta Summer         0.75         Algeent Sulta Summer         0.75           Maxemment Type         Blower Door         Maxemment Type         Blower Door         Propend ACHE SUP         Propend ACHE SUP           Maxemment Type         Blower Door         Adgeent Subala Water         Note         Propend ACHE SUP         Propend ACHE SUP </td <td></td> <td></td> <td>To Bottom of Window (ft)</td> <td>0</td> <td></td> <td></td> <td>To Top of window</td> <td>0</td>			To Bottom of Window (ft)	0			To Top of window	0
Interior State Summer         0.7         Adjecter State Summer         0.7           Note         Adjecter State Summer         Note         Note           Number State Summer         Note         Note         Note           Masserement Type         Boort Door State Summer         Note         Note           State Door Nation State Summer         State Summer         Note         Note           State Door Nation State Summer         State Summer         Note         Note         Note           State Door Nation State Summer         Note         Note         Note         Note         Note           State Door Nation State Summer         Note         Note <td>Interior Shade Winter</td> <td>0.85</td> <td>Interior Shade Winter</td> <td>0.85</td> <td></td> <td></td> <td>Interior Shade Winter</td> <td>0.85</td>	Interior Shade Winter	0.85	Interior Shade Winter	0.85			Interior Shade Winter	0.85
Image: Note: Adding Summer         Adding Summer         None         Image: Summer         None           NETLEXATION         Adding Summer         None         None         None         None           New Door Values (ACH#S SPA         6.99         6.99         Door Values (ACH#S SPA         6.99         Phones ACH#S SPA         7           Baver Door Values (ACH#S SPA         6.99         Conting Secon Inflution (ACHs)         7         Phones ACH#S SPA         7           Baver Door Values (ACH#S SPA         6.99         Conting Secon Inflution (ACHs)         7         Phones ACH#S SPA         5           COULSC         Wethnical Wethnics (Wethnics)         7         Phones ACH#S SPA         5         Secon Inflution (ACHs)         7           Type         Boor No         Methnical Wethnics (Wethnics)         No         Secon Inflution (ACHs)         7         Phones ACH#S SPA         Secon Inflution (ACHs)         7           Type         Boor No         Methnical Wethnics (Wethnics)         No         Secon Inflution (ACHs)         7         Phones ACH#S SPA         Secon Inflution (ACHs)         No           State         Type         Boor No         Methnical Wethnics (Wethnics)         No         Secon Inflution (ACHs)         No         Secon Inflution (ACHs)         No         Se	Interior Shade Summer	0.05	Interior Shade Summer	0.02			Interior Shade Summer	0.02
Image: Second Ration (Adap of the second Ration (Adap of t			Adjacent Shading Summer	None				
INFLITION         Instrument Type         Bower Dorr         Maximeter Type         Bower Dorr           Bower Dorr Vales (ACH@ SDPa)         6.99         Configuration (ACHa)         7         Proposed ACH@ SDPa         7           Bower Dorr Vales (ACH@ SDPa)         6.99         Configuration (ACHa)         7         Proposed ACH@ SDPa         7           Steller Cass         Type         Steller Cass         Framin Frameneer         Substanta           DYP         Bower Dorr Vales (ACH@ SDPa)         7         Steller Configuration (ACHa)         7           Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7         Framin Frameneer         Substanta           Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7           Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7           Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7           Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7         Steller Configuration (ACHa)         7           Steller Configuration (ACHa)         7			Adjacent Shading Winter	None				
Measurement Type         Blower Door         Measurement Type         Blower Door         Conling Season Infinition (ACHu)         T         F <td>INFILTRATION</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>-</td> <td></td>	INFILTRATION						-	
Bioley Dorivanes (ACH/#30 Pa)         Heang Season Infinition (ACHa)         P         Performance (ACH/#30 Pa)         P           Image Season Infinition (ACHa)         A         Selec Cass         A         F         F         F         F         F         Selec Cass         A         F         F         F         F         F         Selec Cass	Measurement Type	Blower Door	Measurement Type	Blower Door				
Image: state of the s	Blower Door Values (ACH@50 Pa)	6.99	Heating Season Infiltration (ACH50)	7			Proposed ACH@50 Pa	7
Image: Section of the sectio			Cooling Season Infiltration (ACH50)	7			-	
Image: space of the space o		1	Shelter Class	4				1
Image: space of the s							Terrain Parameter	Suburban
COOLING         Mechanizal formation         No         Mechanizal formation         No           Type         Becrick         Type         SIR         0.027         SIR         0.027         SIR         0.027         SIR         0.023         SIR         0.023         SIR         0.021         SIR         SIR         SIR         SIR         0.021         SIR			2009 IECC Verification	Tested			Sheilding Coefficient	Suburban
COOLINGmean <t< td=""><td></td><td></td><td>Mechanical Ventilation</td><td>No</td><td></td><td></td><td>Ventilation Air</td><td>None</td></t<>			Mechanical Ventilation	No			Ventilation Air	None
Type         Bectic         Type         Bectic         Type         Decide         Type         Control Unit/ Bectic           SIR         0.027         SIR         0.027         SIR         0.027         SIR         0.027           SIR         13         SIR         0.02         SIR         0.02         SIR         0.02           Capacity (dbu/n)         0         Capacity (dbu/n)         0         Capacity (dbu/n)         0           Stapp         Capacity (dbu/n)         0         Capacity (dbu/n)         0         Capacity (dbu/n)         0           Stapp         Stapp <td>COOLING</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	COOLING							
SIRE         O.C.T         FIRE         O.C.T         SIRE         O.C.T           Capacity (MBurly)         60         Capacity (MBurly)         60         Capacity (MBurly)         60           Capacity (MBurly)         60         Capacity (MBurly)         60         Capacity (MBurly)         60           Supply CPM (CFM (Cond)         300         Capacity (MBurly)         60         Capacity (MBurly)         60           Supply CPM (CFM (Cond)         300         Fuel field at System Type         Fuel field at Gastribution         Fuel Type         Natural gas System Type         Fuel Type         Natural gas System Type         Fuel Type         F	Туре	Electric	Туре	Electric	Туре	Electric	Туре	Central Unit /
Since         Out         Name         Out         State         Out           Opencing (Maturhy)         40         Capacity (Maturhy)         0         Capacity (Maturhy)         0           Capacity (Maturhy)         0         Capacity (Maturhy)         0         Capacity (Maturhy)         0           Supply CIM (CM/ too.)         360         Location         Attic         Location         Attic           Type         Natural gas         System Type         File Type         Natural gas         System Type         File Type         Natural gas           Capacity (Maturhy)         0         Capacity (Maturhy)         0         Natural gas         System Type         File Type         F	SHB	0.627	erm	0.627			SUB	electric 0.622
Constant	SFFR	13	SFER	13	SEER	13	SFER	13
InclusionArtic Supply CPM (CPM ( $rms on marked on marked$	Canacity (kBtu/hr)	60	Capacity (kBtu/hr)	60	olar	1.5	Canacity (kBtu/hr)	60
Supply CPM (CPM / Ion)         360         Incode (3 Air Bow (CPM))         1,800           HEATUNG         Total Cal Air Bow (CPM)         1,800           Type         Natural gas         Fuel Type         Natural gas         Fuel Type         Natural gas         Fuel Type         Natural gas           APLEYs()         78         Efficiency (APUE %)         78         Efficiency (APUE %)         78         Efficiency (APUE %)         78           Copacity (Blun hr)         60         Copacity (Blun hr)         60         Ecation         Attic         Efficiency (APUE %)         78           Copacity (Blun hr)         0         Ausilary Energy Use (kWhrs)         0         Ausilary Energy Use (kWhrs)         60         Ecation         Attic           Ductaction         Attic         Sapply R-value         6         Sapply R-value         6         Sapply R-value         6           Supply Duct Area (agf)         65         Sapply R-value         6         Sapply R-value         6           Supply Duct Area (agf)         500         Return R-value         6         Sapply R-value         6           Duct Leation         Attic         Duct Leation         Attic         Duct Leation         Attic           Duct Leation         Attic	Location	Attic	Location	Attic	Location	Attic	Location	Attic
Image: Second s	Supply CFM (CFM/ ton)	360					Tested Coil Air Flow (CFM)	1,800
Type         Natural gas         Fuel Type         Natural gas         Fuel Type         Natural gas           APLE(%)         78         Efficiency (AFUE %)         78         Efficiency (AFUE %)         78         System Type         Fuel Type         Natural gas         System Type         Fuel Type         Natural gas           APLE(%)         78         Efficiency (AFUE %)         78         Efficiency (AFUE %)         78         Efficiency (AFUE %)         78           Ausliary Farey Use (MWns)         0         Location         Attic         Location         Attic         Location         Attic           Ausliary Farey Use (MWns)         0         Ausliary Farey Use (MWns)         0         Suppl Nevalae         6         Suppl Nevalae         6           Suppl Nevalae         6         Suppl Nevalae         6         Suppl Nevalae         6           Return Rvalae         6         Suppl Nevalae         6         Suppl Nevalae         6           Duct Location         Attic         Duct Area (qt)         70         Suppl Nevalae         6           Return Rvalae         125         Return Rvalae         6         Suppl Nevalae         6           Duct Location         Attic         Duct Location         Attic	HEATING							
Image: System Type         Fuel-field at distribution of the strubule of the s	Туре	Natural gas	Fuel Type	Natural gas	Fuel Type	Natural gas	Fuel Type	Natural gas
Image: space of the s			Sustam Tuna	Fuel-fired air	Sustan Tuna	Fuel-fired air	Sustan Tuna	Fuel-fired air
AFUE(%)         78         Efficiency (AFUE %)         78         Efficiency (AFUE %)         78           Capasity (Blu/hr)         60         Location         Attic         Capasity (Blu/hr)         60           Location         Attic         Location         Attic         Capasity (Blu/hr)         60           Supply Rengy Use (kWhs)         0         Location         Attic         Location         Attic           Supply R-value         6         Supply R-value         6         Supply R-value         6           Supply R-value         6         Return R-value         6         Supply R-value         6           Supply R-value         6         Return R-value         6         Supply R-value         6           Supply R-value         6         Return R-value         6         Supply R-value         6           Duct Location         Attic         Duct Location         Attic         Supply R-value         6           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location S(+R)         Duct Location (S+R)         Duct Location <td></td> <td></td> <td>System Type</td> <td>distribution</td> <td>System Type</td> <td>distribution</td> <td>System Type</td> <td>distribution</td>			System Type	distribution	System Type	distribution	System Type	distribution
Capacity (Blunkr)60Capacity (Blunkr)60Capacity (Blunkr)60LocationAtticLocationAtticLocationAtticAuxilary Energy Use (Whrs)0Auxilary Energy Use (Whrs)0AtticLocationAtticSupply R value6Supply Dict Area (sqft)675Supply Dict Area675Supply Dict Area (sqft)500Return R-value6Supply Dict Area (sqft)675Supply Dict Area675Supply Dict Area (sqft)500Return Duct Area125Return Duct Area125Return Duct Area125Duct LocationAtticDuct LocationAtticDuct LocationAtticDuct LocationAtticDuct LocationAtticDuct Laskage to Outdoon (S+R)UCFM @25Pa)200CFM @25Pa)Duct Laskage to Outdoon (S+R)C(FM @25Pa)Duct Laskage to Outdoon (S+R)C(FM @25Pa)CypeNatural gasCapacity (Galons)40Capacity (Galons)40Capacity (Galons)40Capacity (Galons)0.99Recvery Efficiency0.78Coning (P)75ScheduleConing (P)75Heating (P)72Topic (Finic (P)72Topic (P)72Heating (P)72Heating (P)72Coning (P)72Heating (P)72Heating (P)0.63Eiphing (Wiv)0.63ConstantScheduleConstantScheduleConstantEiphing (Wiv)0.63ConstantScheduleConstant <t< td=""><td>AFUE(%)</td><td>78</td><td>Efficiency (AFUE %)</td><td>78</td><td>Efficiency (AFUE %)</td><td>78</td><td>Efficiency (AFUE %)</td><td>78</td></t<>	AFUE(%)	78	Efficiency (AFUE %)	78	Efficiency (AFUE %)	78	Efficiency (AFUE %)	78
Location         Attic         Location         Attic         Location         Attic           Auxiliary Energy Use (kWhrs)         0         Incomposition         Attic         Incomposition         Attic           Supply R-value         6         Supply R-value         6         Supply R-value         6           Return R-value         6         Supply R-value         6         Supply R-value         6           Supply R-value         6         Return R-value         6         Supply R-value         6           Supply R-value         6         Return R-value         6         Supply R-value         6           Duct Laration         Attic         Incomposition         Attic         Incomposition         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Mattic Lasage to Outdoors (S+R)	Capacity (kBtu/hr)	60	Capacity (kBtu/hr)	60		41	Capacity (kBtu/hr)	60
Auxility Energy Use (LW fix)         0         Auxility Energy Use (LW fix)         0           Supply R-value         6         Supply R-value         6           Supply Duct Area (sqf)         675         Supply Duct Area         6125           Patturn R-value         1         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic           Duct Laskage to Outdoors (S+R)         Use Measured Laskage         Yes (CM@ 2SPa)         Duct Location         Attic           Duct Laskage to Outdoors (S+R)         CPM @2SPa)         200         CPM @2SPa)         Duct Laskage to Outdoors (S+R)         CPM @2SPa)           Type         Natural gas         Type         Natural gas         Type         Natural gas           Rated Input (Burbry)         36,000         Cpaceity (Callons / Day)         60         Type         Natural gas           Recovery Efficiency         0.78         Recovery Efficiency         0.78         Cpaceity (Callons / Day)         60           Recovery Efficiency	Location	Attic	Location	Attic	Location	Attic	Location	Attic
DUCLS         Supply N-value         6         Supply N-value         6           Return R-value         6         Return R-value         6         Return R-value         6           Supply N-value         6         Supply N-value         6         Return R-value         6           Supply N-value         6         Supply N-value         6         Return N-value         6           Supply N-value         6         Supply N-value         6         Return N-value         6           Return Duct Area         125         Return Duct Area         125         Return Duct Area         125           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Lakage to Cutdoons (S+R)         Use Messured Leakage to Yes (CFM @2Pa)         Duct Lakage to Cutdoons (S+R)         UCFM @2 Pa)         Duct Lakage to Cutdoons (S+R)           (CFM @2 Pa)         200         Type         Natural gas         Type         Natural gas           Rated Input (Bu/hr)         36,000         Capacity (Gallons / Day)         60         Water Usage (Gallons / Day)         60           Recovery Efficiency         0.79         Recovery Efficiency         0.79         Recovery Efficiency         0.79           Returel	Auxiliary Energy Use (kWhrs)	0	Auxiliary Energy Use (kWhrs)	0				
Suppy R-value         0         Suppy R-value         0           Suppy R-value         6         Return R-value         6           Suppy R-value         6         Return R-value         6           Suppy Duct Area (sqfl)         675         Suppy Duct Area         675           Return R-value         8         Return R-value         6           Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic           Duct Location         CFM @25 Pa)         200         Uct Measured Leakage to Valuos (S+R)         Uct Measured Leakage to Valuos (S+R)           (CFM @25 Pa)         200         Uct Marge to Outdoos (S+R)         Uct Measured Leakage to Valuos (S+R)         Uct Measured Leakage (Valuos Valuos (S+R)         Uct Measured Leaka	DUCIS		Successive Describer				Secondar Directory	6
Declame Analos         O         Return Nation         O         Return Nation         O           Return Duct Area (qft)         675         Supply Duct Area         675         Return Duct Area         125           Return Duct Area         125         Return Duct Area         125         Return Duct Area         615           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location Serst         Tested         Use Measured Leakage to Outdoors (S+R)         Duct Leakage to Outdoors (S+R	Suppiy K-value Paturn P value	6	Supply K-value	6			Suppry K-value Paturn P value	6
Subject Nak (Eq(i))         OF         Subject Nak (Eq(i))         OF         Subject Nak (Eq(i))         OF           Setum Duct Area         125         Return Duct Area         125         Return Duct Area         125           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Duct Location         Attic         Duct Location         Attic         Duct Location         Attic           Type         Natural gas         C(FM@ 25 Pa)         200         C(FM@ 25 Pa)         200           HOT WATER         Type         Natural gas         Type         Natural gas         Type         Natural gas           Capacity (Gallons)         40         Capacity (Gallons)         40         Capacity (Gallons)         40           Water Usage Gallons / Day)         60         Energy Factor         0.59         Energy Factor         0.59 <t< td=""><td>Supply Duct Area (caft)</td><td>675</td><td>Supply Duct Area</td><td>675</td><td></td><td></td><td>Supply Duct Area (coff)</td><td>500</td></t<>	Supply Duct Area (caft)	675	Supply Duct Area	675			Supply Duct Area (coff)	500
Attic     Beam Jack mean     Jack       Duct Location     Attic     Dect Location     Attic       Duct Tightness Test     Tested advector     Attic     Duct Location     Attic       Duct Laskage to Outdoors (S+R)     Use Measured Laskage     Yss (CFM@ 2SPa)     Duct Laskage to Outdoors (S+R)     CFM@ 2SPa)     Duct Laskage to Outdoors (S+R)     CFM@ 2SPa)     Duct Laskage to Outdoors (S+R)     Duct Laskage to Outdoors (S+R)     Duct Tightness Test     Anticipated       Type     Natural gas     Type     Natural gas     Type     Natural gas     Type     Natural gas       Capacity (Gallons / Day)     60     Date Tightness (Test)     Open type     Natural gas     Type     Natural gas       Capacity (Gallons / Day)     60     Date Tightness (Test)     Open type     Open type     Open type     Natural gas     Type     Natural gas       Capacity (Gallons / Day)     60     Date Tightness (Test)     Open type     Op	Return Duct Area	125	Return Duct Area	125			Return Duct Area	125
Duct Location     Attic     Duct Location     Attic       Duct Lackage to Sutdoors (S+R)     Use Measured Leakage     Yes (CFM @ 25Pa)       Duct Lackage to Outdoors (S+R)     Duct Lackage to Outdoors (S+R)     Duct Lackage to Outdoors (S+R)       (CFM @ 25 Pa)     200     (CFM @ 25 Pa)     Duct Lackage to Outdoors (S+R)       Type     Natural gas     Type     Natural gas       Rated Input (Bwhr)     36,000     Capacity (Gallons)     40       Water Usage (Gallons / Day)     60     Water Usage (Gallons / Day)     60       Recovery Efficiency     0.78     Recovery Efficiency     0.78       Temperature Setting (F)     120     Energy Factor     0.59       Cooling (F)     72     Heating (F)     72       Heating (F)     72     Heating (F)     72       Schedule     Constant     Lighting (kW)     0.47       Lighting (kW)     0.63     Equipment (kW)     0.63	Ductinu		# Return	1				
Duct Taghness Test         Tested         Use Measured Leakage         Yes (CFM @2SPa)         Duct Taghness Test         Anticipated           Duct Lakage to Outdoors (S-R)         0         Duct Lakage to Outdoors (S+R)         0         0         Duct Lakage to Outdoors (S+R)         0	Duct Location	Attic	Duct Location	Attic	Duct Location	Attic	Duct Location	Attic
Duct Lakage to Outdoors (S+R)         Du	Duct Tightness Test	Tested	Use Measured Leakage	Yes (CFM@25Pa)			Duct Tightness Test	Anticipated
(cTM@25 Pa)         200         (CTM@25 Pa)         200           HOT WATER         Type         Natural gas         (CTM@25 Pa)         200           Lorgacity (Gallons)         36,000         Type         Natural gas	Duct Leakage to Outdoors (S+R)		Duct Leakage to Outdoors (S+R)				Duct Leakage to Outdoors (S+R)	
HOT WATER         Type         Natural gas         Type         Natural gas         Type         Natural gas           Rated Input (Bu/hr)         36,000         Capacity (Gallons)         40         Capacity (Gallons)         40         Capacity (Gallons)         40           Vater Usage (Gallons / Day)         60         Water Usage (Gallons / Day)         60         Capacity (Gallons)         40           Water Usage (Gallons / Day)         60         Energy Factor         0.59         Energy Factor         0.59           Recovery Efficiency         0.78         Recovery Efficiency         0.78         Energy Factor         0.59           Conjng (b)         75         Cooling (F)         75         Cooling (F)         75           Heating (F)         72         Heating (F)         72         Heating (F)         72           APPLIANCES & LIGHTS         Schedule         Constant         Schedule         Constant           Lighting (W)         0.63         Equipment (W)         0.63         Equipment (W)         0.63	(CFM@25 Pa)	200	(CFM@25 Pa)	200			(CFM@25 Pa)	200
Type         Natural gas         Type         Natural gas         Type         Natural gas           Rade Input (Burhyn)         36,000         - <td>HOT WATER</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>	HOT WATER							
Rated Input (Baruh?)         35,000	Туре	Natural gas	Туре	Natural gas			Туре	Natural gas
Capacity (Gallons)         40         Capacity (Gallons)         40           Water Usage (Gallons / Day)         60         Water Usage (Gallons / Day)         60           Energy Factor         0.59         Energy Factor         0.59           Recovery Efficiency         0.78         Recovery Efficiency         0.78           Temperature Strings (F)         120             Cooling (P)         75         Cooling (F)         75           Heating (F)         72         Heating (F)         72           APPLIANCES & LIGHTS         Schedule         Constant           Lighting (kW)         0.47         Lighting (kW)         0.47           Lighting (kW)         0.63         Equipment (kW)         0.63	Rated Input (Btu/hr)	36,000						
Water Usage (kilons / Day)         60         Water Usage (kilons / Day)         60         Water Usage (kilons / Day)         60           Bergy Factor         0.59         Energy Factor         0.59         Energy Factor         0.59           Recovery Efficiency         0.78         Recovery Efficiency         0.78         Energy Factor         0.59           Temperature Strings (F)         120         Image: Cooling (F)         75         Image: Cooling (F)         75           Cooling (F)         75         Cooling (F)         72         Image: Cooling (F)         72           APPLIANCES & LIGHTS         Schedule         Constant         Schedule         Schedule         Constant           Lighting (kW)         0.47         Lighting (kW)         0.47         Schedule         Constant           Lughting (kW)         0.63         Equipment (kW)         0.63         Equipment (kW)         0.63	Capacity (Gallons)	40	Capacity (Gallons)	40			Capacity (Gallons)	40
Integy ration         0.39         Integy ration         0.39           Recovery Efficiency         0.78         Integy ration         0.39           Temperature Settings (F)         120         Integy ration         0.78           Temperature Settings (F)         120         Integy ration         0.78           Cooling (P)         75         Cooling (F)         75           Heating (P)         72         Heating (F)         72           APPLIANCES & LIGHTS         Schedule         Constant           Schedule         Constant         Schedule         Constant           Lighting (W)         0.63         Epipment (W)         0.63         Epipment (W)         0.63           Note         Kote         Kote         Kote         Kote         Kote	water Usage (Gallons / Day)	60	Water Usage (Gallons / Day)	60			Water Usage (Gallons / Day)	60
PRCOVEY LINKENCY         0./8         RECOVEY Elicency         0./8         Image: Constant Sector 1 and Sector 1 a	Energy Factor	0.59	Energy Factor	0.59			Energy Factor	0.59
Cooling (P)         75         Cooling (F)         75         Cooling (F)         75           Heating (P)         72         Heating (F)         72         Heating (F)         72           APPLIANCES & LIGHTS         Schedule         Constant         Schedule         Schedule         Constant           Lighting (W)         0.63         Equipment (W)         0.63         Equipment (W)         0.63         Schedule         Constant           Vorte<	Temperature Settings (F)	0.78	Recovery Efficiency	0.78				
Alexit CNAS         Cooling (F)         75         Cooling (F)         75           Heating (F)         72         Heating (F)         72         Heating (F)         72           APPLIANCES & LIGHTS         Image: Constant         Schedule         Constant         Schedule         Constant           Schedule         Constant         Schedule         Constant         Schedule         Schedule         Constant           Lighting (kW)         0.47         Lighting (kW)         0.47         Lighting (kW)         0.63         Equipment (kW)         0.63         Constant	TEMDEDATUDES	120		1				1
Cooling (Y)         Cooling (Y) <thcooling (y)<="" th=""> <thcooling (y)<="" th=""></thcooling></thcooling>	Cooling (E)	75	Cooling (E)	75			Cooling (E)	75
APPLIANCES & LIGHTS     Iteaug (V)     12       Schedule     Constant     Schedule     Constant       Lighting (W)     0.47     Lighting (W)     0.47       Equipment (W)     0.63     Equipment (W)     0.63	Heating (F)	72	Heating (F)	72			Heating (F)	72
Schedule         Constant         Schedule         Constant         Schedule         Constant           Lighting (kW)         0.47         Lighting (kW)         0.47         Lighting (kW)         0.47           Equipment (kW)         0.63         Equipment (kW)         0.63         Equipment (kW)         0.63	APPLIANCES & LIGHTS	12	round (r)	12			incuring (1)	12
Constant	Schedule	Constant	Schedule	Constant			Schedule	Constant
Equipment (kW)         0.63         Equipment (kW)         0.63         Equipment (kW)         0.63           Note:                 0.63            0.63            0.63            0.63            0.63            0.63             0.63            0.63            0.63             0.63            0.63            0.63            0.63             0.63             0.63               0.63	Lighting (kW)	0.47	Lighting (kW)	0.47			Lighting (kW)	0.47
Note:	Equipment (kW)	0.63	Equipment (kW)	0.63			Equipment (kW)	0.63
	Note:							

 Table 1: Input for the Proposed Base-Case House in the Four Software Programms to Comply with the 2009 IECC (Continued)

Cells marked in yellow indicate information specific to the Climate Zones selected by this analysis.

### RESULTS FROM SENSITIVITY ANALYSIS

This section provides the results of the sensitivity tests that were performed for parameters that include House size, Window-to-wall area ratio, Wall insulation, Ceiling insulation, Window SHGC, Window U-value, and Slab R-value. The analysis was performed by changing the value of each parameter and documenting the resultant percentage difference above/below the 2009 IECC Reference house.

# *Variations in House Size (Fixed window area of 60 ft<sup>2</sup> per orientation):*

The comparison for the variation in house size is presented in Figure 4. For the 2,500 ft<sup>2</sup> house, for the three Climate Zones, the results of the four software programs are similar to each other. For the 1,000 ft<sup>2</sup> house, the fixed window area of 60 ft<sup>2</sup> per orientation of the Proposed house is greater than the 15% window-to-floor area ratio limit specified for the Reference house in the 2009 IECC<sup>21</sup>. Hence, the Proposed house is more consumptive than the corresponding Reference house. For Houston, the results from Software 1, Software 2 and Software 3 are consistently lower than the corresponding Reference house (8.8% -10.6% below code). Results from Software 4 are less sensitive (3.1% below code). For Dallas, the results from Software 2 and Software 3 are consistent with each other (6.3% - 6.6% below code). Results from Software 1 are more sensitive than the results from the other three software programs (10% below code). Results from Software 4 are least sensitive when compared with the results from the other three software programs (2.6% below code). For Amarillo, results from Software 1 and Software 2 are consistent with each other (8.7% - 8.4% below code). Results from Software 3 and Software 4 are consistent with each other (3.6% - 2.7% below code). For house sizes greater than 2,500 ft<sup>2</sup>, the results are consistent with each other (within 1% of the code).

## Variations in House Size (Fixed window-to-wall area of 15%):

The comparison for the variation in house size is presented in Figure 5. For the 2,500 ft<sup>2</sup> house, for the three Climate Zones, the results of the four software programs are similar to each other. For the 1,000 ft<sup>2</sup>, a window-to-wall area ratio of 15% per orientation is greater than the 15% windowto-floor area ratio limit specified for the Reference house in the 2009 IECC. Hence, in this case the Proposed house is more consumptive than the corresponding Reference house. In all Climate Zones, house the difference in the results from the four software programs is within 4%. For all other house sizes, in all Climate Zones, results of the four software programs are similar to each other with differences within 2%.

#### Variation in Window-to-wall Area Ratio:

The comparison for the variation in window-towall area ratios is presented in Figure 6. 60 ft<sup>2</sup> of window area assumed in the Proposed design base-case corresponds to 15% window-to-wall area ratio. For window-to-wall area ratio of 10% and 20% results from the four software programs are similar (within 1% of the code). For windowto-wall area ratios of 30%, 40% and 50% considered for the analysis, the resultant window areas are greater than the 15% window-to-floor area ratio limits specified in the 2009 IECC. Hence the Proposed house is more consumptive than the corresponding Reference house. For Houston, the results of Software 1, Software 2 and Software 3 are similar (for 50% WWAR, 25% - 28.9% below code). Results from Software 4 are least sensitive (for 50% WWAR, 10.5% below code). For Dallas, results of Software 2 and Software 3 are similar (for 50% WWAR, 21.3% - 20% below code). Results from Software 1 are most sensitive (for 50% WWAR, 26.5% below code) and results from Software 4 are least sensitive (for 50% WWAR, 8.5% below code). For Amarillo, results from all four software are different with results from Software 1 being most sensitive (for 50% WWAR, 26.5% below code) and results from Software 4 being least sensitive to change in window area (for 50% WWAR, 8.9% below code). It is also noted that Software 2 and Software 3 provide similar results for Houston and Dallas, for Amarillo, results from Software 3 become less sensitive to variation in window-to-wall area ratio.

#### Variation in Wall Insulation:

The comparison for the variation in wall insulation is presented in Figure 7. It should be noted that the wall insulation is increased by adding continuous insulation in addition to the R-13 cavity insulation specified in the 2009 IECC. For the 2009 IECC compliant case (R-13+0), the four software programs provide similar answers (within 1% of the code). For cases with greater wall insulation, for Houston, results from the Software 1, Software 2 and Software 3 are similar (for R-13+9 wall insulation, 6% - 6.5% above code). Results from Software 4 are less sensitive than the other software programs (for R-13+9 wall insulation, 3.5% above code). For Dallas and Amarillo, results from Software 1 and Software 2 are similar (for R-13+9 wall insulation, 7.1% -6.4% above code for Dallas, 8.8% - 7.7% above code for Amarillo). Results from Software 4 are less sensitive than the other software programs (for R-13+9 wall insulation, 3.4% above code for Dallas, 5.4% above code for Amarillo). Results for Software 3 are more sensitive than the other software programs (for R-13+9 wall insulation, 8% above code for Dallas, 11% above code for Amarillo).

<sup>&</sup>lt;sup>21</sup> Table 405.5.2(1), Glazing, 2009 IECC.

#### Variation in Ceiling Insulation:

The comparison for the variation in ceiling insulation is presented in Figure 8. For the 2009 IECC compliant case, the four software provide similar answers (within 1% of the code). For ceiling insulation of R-60, results from the four software diverge and are within 9%, with pattern of divergence remaining regardless of the Climate Zone (for R-60 ceiling insulation, 1.9% - 9% above code for Houston, 1.9% - 12% above code for Dallas, 1.8% - 10.7% above code for Amarillo). When considering results from Software 1 and Software 2, variations in results are within 5%.

#### Variation in Window SHGC:

The comparison for the variation in window SHGC is presented in Figure 9. For the 2009 IECC compliant values for SHGC results from the four software programs are consistent for the three Climate Zones (within 1% of the code). For window SHGC of 0.5, for Houston and Dallas, the Proposed house is more consumptive than the corresponding Reference house. The results from the four software programs are within 4% (1.8% - 5.7% below code for Houston, 0.3% - 3.4% below code for Dallas). On the other hand for Amarillo, the Proposed house is as consumptive or more efficient than the corresponding Reference house depending on the software used (Software 3 provides 2.5% savings above code; Software 1, Software 2 and Software 4 provide within 1% savings of the code). For window SHGC of 0.2. for Houston. Dallas & Amarillo results from the four software programs are within 1.4%.

#### Variation in Window U-value:

The comparison for the variation in window Uvalues is presented in Figure 10. For the 2009 IECC compliant case, the four software provide similar answers (within 1% of the code). For Uvalue of 0.75, for Houston, the four software programs show similar results (0.4% - 1.7% below code). For Dallas, Software 1, Software 2 and Software 3 show similar results (4.9%, 5% and 6% below code). Software 4 is the least sensitive (2% below code). Similarly for Amarillo, Software 1, Software 2 and Software 3 show similar results (13.9%, 16.1%, 14% below code). Software 4 does not support this input and hence the results from Software 4 was not available. When considering the U-value of 0.25, for Houston, variation in results from Software 1. Software 2 and Software 3 are within 5% of each other with results from Software 2 being the most sensitive (6.3% - 10.1% above code). However, results from Software 4 are least sensitive to the change in U-value (3% above code). For Dallas, the results from the four software programs are within 5% of each other with results from Software 1, Software 2 and Software 3 being similar (6.1% - 8% above code) and results from Software 4 being the least sensitive (2.7% above code) to the change in U-value. For Amarillo, similar trends are observed for the four software programs (2.3% - 5.8% above code).

#### Variation in Slab R-value:

The comparison of slab R-values is presented in Figure 11. Since there are no requirements in the 2009 IECC for slab insulation in Climate Zone 2 and Climate Zone 3, the analysis is performed only for Amarillo, Climate Zone 4. For the 2009 IECC compliant case the four software programs provide similar results (within 1% of the code). For un-insulated floor slab (R-0), results from Software 1, Software 2 and Software 3 are within 10%. However, results from Software 4 are extremely sensitive with greater than 35% below code compliant base-case. For the slab insulation of R-15, results from Software 1, Software 2 and Software 4 are similar. Software 3 does not support the input for R-15 for the slab. Hence the result from Software 3 was not available.

#### **SUMMARY & DISCUSSIONS**

This analysis explores the differences in results obtained from the four software programs that are currently used for performance path compliance with the 2009 IECC in the State of Texas. Three of the Software programs used for the analysis are certified by RESNET. A 2009 IECC compliant house was used to perform the analysis. 500  $ft^2$ /ton of refrigeration (500  $ft^2$ / 12000 Btu/hr for heating) is used to size the cooling systems in the Proposed house for Software 1, Software 2 and Software 3. When sizing systems for the Reference house, 500  $ft^2$ /ton is used to size the cooling systems in Software 3. However, Software 2 uses a different criteria to size cooling and heating systems.

For variations in parameters such as house size, exterior wall insulation, window SHGC and window U-value, the sensitivity analysis indicates a variation within 5% for the RESNET certified software programs considered for the analysis. However, variation in results from the three RESNET certified software programs exceeds 5% in certain cases of ceiling R-values in all climate zones and in certain cases of windowto-wall area ratios in Climate Zone-4.

It should also be noted that system sizing for Software 1 and Software 3 were set at 500 ft<sup>2</sup>/ton for both the reference house and proposed house. Systems for Software 2 was auto-sized. For the condition of ducts in attic, the system sizing for Software 2 were similar to the sizing values of other two software programs. Although system sizing does not play a significant role in the analysis described by this paper, variations in system sizing were the cause of variation in results in cases other than what was selected for this paper such as ducts in conditioned space (Mukhopadhyay et al. 2012).

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Figure 4: Variation in Size of House (Fixed Window Area)



Figure 5: Variation in Size of House (Fixed Window-to-Wall Area Ratio)

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Figure 6: Variation in Window to Wall Area Ratio



**Figure 7: Variation in Wall Insulation** 



**Figure 8: Variation in Ceiling Insulation** 



**Figure 9: Variation in Window SHGC** 



Figure 10: Variation in Window U-values



Figure11: Variation in Slab R-Value