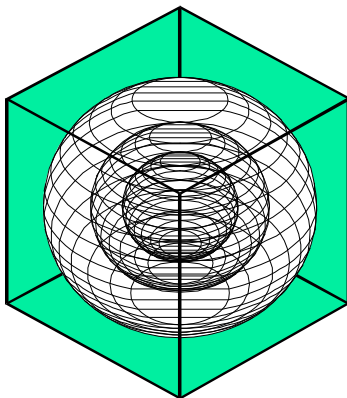# VALIDATION OF THE INTERNATIONAL CODE COMPLIANT CALCULATOR (IC3) v3.10 USING THE RESNET VERIFICATION PROCEDURES (NO. 07-003)

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EXECUTIVE SUMMARY

This report presents results from the testing and validation of the Energy Systems Laboratory's web-based software tool - International Code Compliance Calculator (IC3), v3.10, using the Residential Energy Services Network (RESNET) verification procedures - RESNET Publication No. 07-003. It is the continuation of the previous 2009 RESNET validation report of IC3 v3.3. The IC3 software is a web-based tool to demonstrate compliance of single and multifamily residences with the Texas Building Energy Performance Standards (TBEPS) (i.e., the 2000 International Energy Conservation Code (IECC) with the 2001 Supplement, the 2006 National Appliance Energy Conservation Act (NAECA) revisions, and the 2009 IECC). The user-interface of IC3 was designed to ensure simple and quick input through reduced user input fields and present a simplified output by only reporting the code-compliance as percent above or below code for locations in Texas.

The RESNET verification procedure is a set of verification tests that are required for RESNET accreditation of IECC performance compliance software tools. It was developed to ensure the accuracy and comparability of software to be used for verification of tax credits, home energy ratings, and compliance with the IECC. The verification procedure applies to the 2004 supplement of the IECC and to the 2006 IECC. The home configurations and operating conditions for the Standard Reference Home and Rated Home are required to be adopted from RESNET (2007) or Section 404 of the IECC, supplemented by the 2006 Mortgage Industry National Home Energy Rating System Standards.

To test the IC3 using the RESNET verification test suite, a special version of the Desktop DOE-2 Processor (DDP) spreadsheet was developed since the test runs for RESNET accreditation cannot be performed using the user interface of web-based IC3. The DDP spreadsheet is the ESL's internal desktop version that utilizes the same DOE-2 simulation procedures as the web-based IC3. The DDP spreadsheet has the flexibility to calculate compliance with other codes by auto-generating the corresponding standard reference designs, incorporates additional weather locations, and reports the simulation results in a pre-specified manner as well as modification of selected simulation inputs, which are not available in the user interface of IC3. The DDP spreadsheet can be uploaded to the ESL's web server for processing, and the results can be downloaded after the processing to view the simulation results.

The RESNET verification procedure consists of the five test suites: 1) Tier one of the HERS BESTEST; 2) IECC Code Reference Home auto-generation tests; 3) HVAC tests; 4) Duct distribution system efficiency tests; and 5) Hot water system performance tests. The specifications and acceptance criteria of each test suite and the test results of IC3 are presented in Section 2.1 to 2.5. The results show that IC3 is a code-compliant simulation program that conforms to the acceptance criteria for each test suite.

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1. INTRODUCTION

This report presents results from the testing and validation of the Energy Systems Laboratory's web-based software tool - International Code Compliance Calculator (IC3), v3.10, using the Residential Energy Services Network (RESNET) verification procedures - RESNET Publication No. 07-003. It is the continuation of the previous 2009 RESNET validation report of IC3 v3.3. The IC3 software is a web-based tool to demonstrate compliance of single and multifamily residences with the Texas Building Energy Performance Standards (TBEPS) –i.e., the 2000 International Energy Conservation Code (IECC) with the 2001 Supplement, the 2006 National Appliance Energy Conservation Act (NAECA) revisions, and the 2009 IECC. The user-interface of IC3 was designed to ensure simple and quick input through reduced user input fields and present a simplified output by only reporting the code-compliance as percent above or below code for locations in Texas.

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2. RESNET VERIFICATION TEST SUITE

The RESNET software verification test suite includes the five following tests. The specifications and acceptance criteria of each test suite and the test results of IC3 are presented in Section 2.1 to 2.5.

1) **Tier one of the HERS BESTEST:** for testing the building load prediction accuracy of simulation software. The acceptance criteria are based on reference results from three programs: BLAST 3.0 Level 215, DOE2.1e-W54 and SERIRES/SUNREL 5.7.

2) **IECC Code Reference Home auto-generation tests:** for verifying the ability of the software tool to automatically generate the IECC Standard Reference Design Home given only the building information from the Proposed Homes.

3) **HVAC tests:** for verifying the accuracy and consistency with which software tools predict the performance of HVAC equipment, including furnaces, air conditioners, and air source heat pumps. The acceptance criteria are based on reference results from six tools: two DOE-2.1e tools, two DOE-2.2 tools, MICROPAS version 6.5, and TRNSYS version 15.

4) **Duct distribution system efficiency tests:** for verifying the accuracy with which software tools calculate air distribution system losses, including the impact of duct insulation, duct air leakage, and duct location. The acceptance criteria for these tests were established using ASHRAE Standard 152-2004.

5) **Hot water system performance tests:** for determining the ability of the software to accurately predict domestic hot water system energy use, including: the domestic hot water usage rate (gallons per day) and the climate impacts (inlet water temperatures) of standard gas-fired domestic hot water systems. The acceptance criteria are based on reference results from three software tools: TRNSYS version 15, DOE-2.1e (v.120) as used by EnergyGauge USA version 2.5, and REM/Rate version 12.

2.1. Tier One of the HERS BESTEST

The following test cases are provided by the Tier one of the HERS BESTEST procedure:

- **Case L100:** The Base-Case Building. This is a 1,539 sq.ft., single-story, wood-frame, fully-vented crawlspace home with 270 sq.ft. of single-glazed windows (distributed with 90 sq.ft. on the north and south faces and 45 sq.ft. on the east and west faces). The walls have R-11 cavity insulation and the ceiling and floor have R-19 insulation.

- **Case L110:** High Infiltration (1.5 ACH). The same as Case L100 with the exception of the infiltration rate, which is increased from its base-case value of 0.67 air changes per hour (ACH) to a value of 1.5 ACH.

- **Case L120:** Well-Insulated Walls and Roof. The same as Case L100 except that the wall cavity insulation is increased from R-11 to R-18 with R-7.2 exterior insulation and the ceiling insulation is increased from R-19 to R-57.

- **Case L130:** Double-Pane, Low-Emissivity Windows with Wood Frames. The same as Case L100 except that the single-glazed windows are replaced with high-efficiency windows, which have an overall U-factor of 0.30 and an overall Solar Heat Gain Coefficient (SHGC) of 0.335.

- **Case L140:** Zero Window Area. The same as Case L100 except that the windows are replaced with wood frame walls having R-11 insulation.

- **Case L150:** South-Oriented Windows. The same as Case L100 except that the entire 270 sq.ft. of windows is moved to the south face of the home.

- **Case L155:** South-Oriented Windows with Overhang. The same as Case L150 except that a 2.5 ft. opaque overhang has been included at the top of south exterior wall.

- **Case L160:** East- and West-Oriented Windows. The same as Case L100 except that all the windows are moved to the east and west faces of the building with 50% (135 sq.ft.) on each face.

- **Case L170:** No Internal Loads. The same as Case L100 except that the internal gains are reduced from 68,261 Btu/day to zero.

- **Case L200:** Energy Inefficient. The same as Case L100 except for: i) Infiltration rate is increased from 0.67 ACH to 1.5 ACH, ii) Exterior wall insulation is replaced by an air gap, iii) Crawlspace floor insulation is removed, and iv) Ceiling insulation is reduced from R-19 to R-11.

- **Case L202:** Low Exterior Solar Absorptance. The same as Case L200 except that the solar absorptance of the roof and walls is reduced from 0.6 to 0.2.

- **Case L302:** Uninsulated Slab-on-Grade. The same as Case L100 except that the floor system is changed from a fully-vented crawlspace to an uninsulated, concrete slab-on-grade.

- **Case L304:** Insulated Slab-on-Grade. The same as Case L302 except that R-5.4 exterior foundation insulation is added around the slab perimeter.

- **Case L322:** Uninsulated Conditioned Basement. The same as Case L100 except that the floor system is changed from a fully-vented crawlspace to an uninsulated conditioned basement with 8′ 0″ of the uninsulated basement wall and the uninsulated main floor (basement ceiling).

- **Case L324:** Insulated Conditioned Basement. The same as Case L322 except that R-11 insulation is added at the inside of the basement walls.

Case L100 is the base case against which most other cases are compared to determine if the rating tool can accurately determine energy differences due to changes in building configuration. With the exception of Cases L302, L304, L322, and L324, each of the above test cases was simulated in Colorado Springs, CO to evaluate heating energy loads and in Las Vegas, NV to evaluate cooling energy loads.

Figures 1 and 2 show the 90% confidence intervals for the maximum and minimum ranges of allowable predictions for heating loads (Figures 1a and 1b) and heating load differential (Figures 1c and 1d) in Colorado Springs, CO and cooling load (Figures 2a and 2b) and cooling load differential (Figures 2c and 2d) in Las Vegas, NV, respectively, produced by the three reference programs and compared against the predictions of IC3. All IC3 results fall within the 90% confidence intervals required by HERS BESTEST procedures. For test cases with slab-on-grade floor (L302 and L304), the IC3 results for heating loads are close to the lower bound, while for test cases with all south-oriented windows (L150), the IC3 results for cooling loads are close to the upper bound.
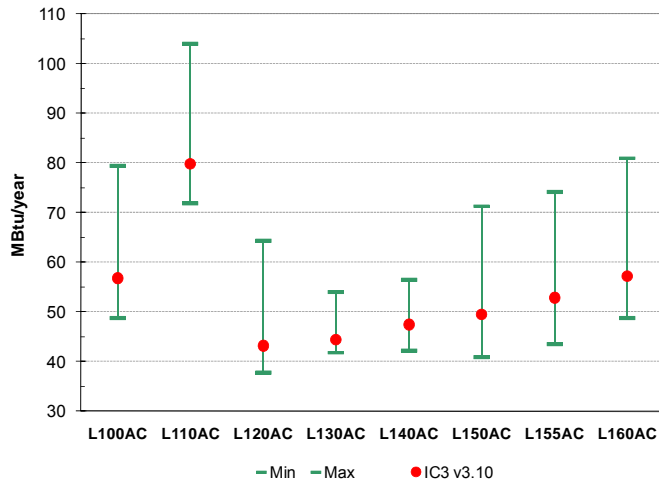
(a) Heating Load Results for Test Cases L100-L160
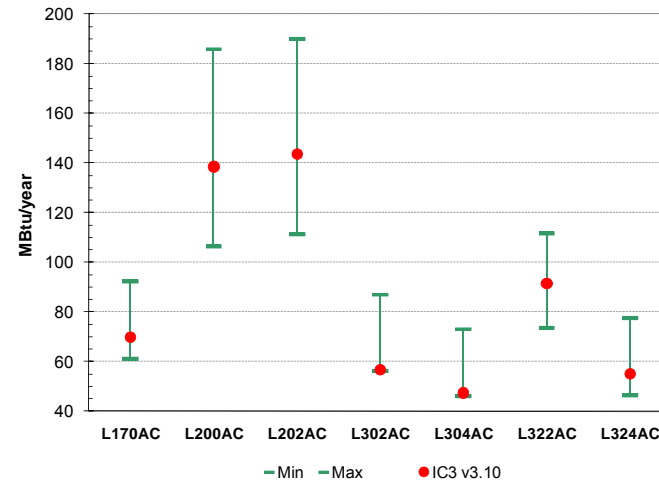
(b) Heating Load Results for Test Cases L170-L324
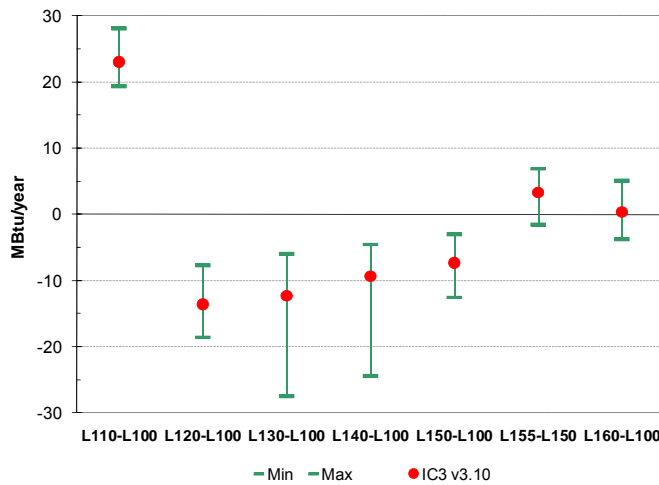
(c) Heating Load Differential Results for Test Cases L110 – L160

(d) Heating Load Differential Results for Test Cases L170 – L324

Figure 1: Heating Load and Heating Load Differential Results Using IC3 in Colorado Springs, CO
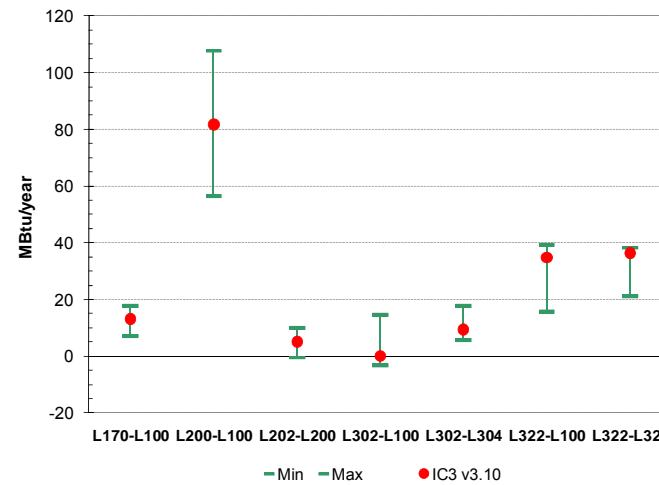
(a) Cooling Load Results for Test Cases L100-L150

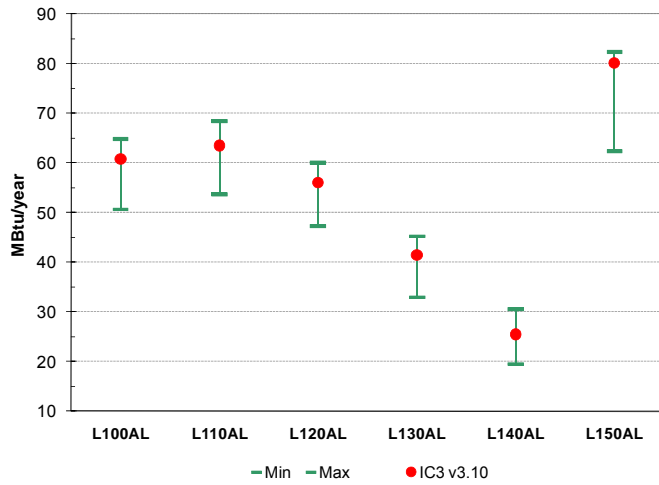(b) Cooling Load Results for Test Cases L155-L202

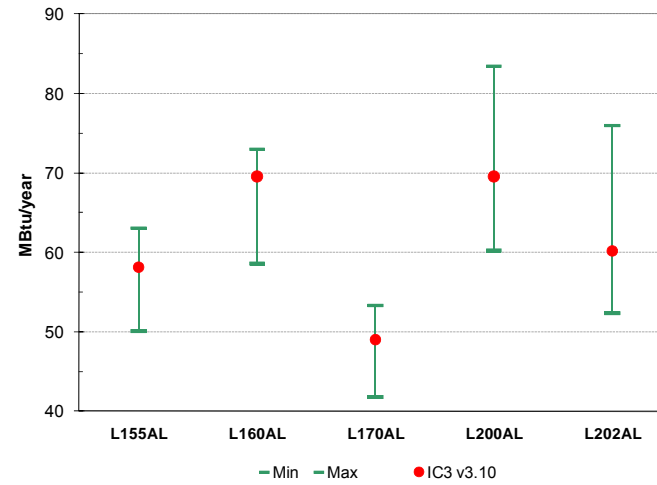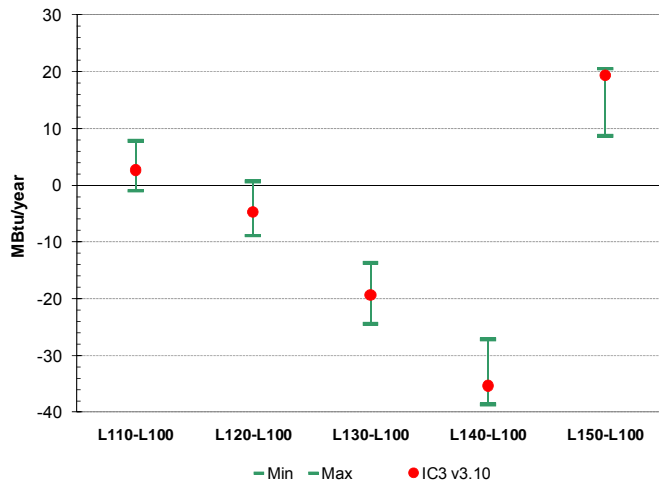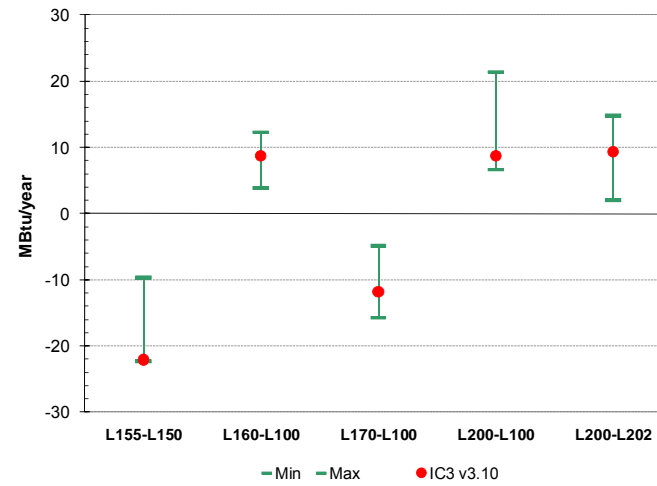(c) Cooling Load Differential Results for Test Cases L110 – L150

(d) Cooling Load Differential Results for Test Cases L155 – L202

Figure 2: Cooling Load and Cooling Load Differential Results Using IC3 in Las Vegas, NV

2.2. IECC Code Reference Home Auto-Generation Tests

This test suite includes the following test cases:

- **Test Case 1.** HERS BESTEST Case L100 with 3 bedrooms, located in Baltimore, MD, and having an 82% AFUE gas furnace and a SEER 11 central air conditioner.

- **Test Case 2.** HERS BESTEST Case L100 with 3 bedrooms, configured on an un-vented crawlspace with R-7 crawlspace wall insulation, located in Dallas, TX, and having a 7.5 HSPF electric heat pump and SEER 12 air conditioner.

- **Test Case 3.** HERS BESTEST Case L304 with 2 bedrooms located in Miami, FL, and having 1 COP electric strip heating and a SEER 15 central air conditioner.

- **Test Case 4.** HERS BESTEST Case L324 with 4 bedrooms, located in Colorado Springs, CO, and having a 95% AFUE gas furnace and no air conditioning.

- **Test Case 5.** Recreate or store the Reference Homes created in Tests 1 through 4 as Rated Homes and simulate and evaluate them.

The minimum acceptance criteria for the software include:

1) The ability to recreate or store the test case Standard Reference Designs as if they were Proposed Homes such that they also can be simulated and evaluated as the Proposed Homes;
2) The ability to report, at a minimum, the values for the Reference Home listed in the column 1 of Table 1; and
3) The energy use e-Ratio, calculated separately from the simulation results for heating and cooling is ± 0.5%, where:

$$\text{e-Ratio} = \frac{\text{(Proposed Home energy use)}}{\text{(Standard Reference Design energy use)}}$$

Table 1 lists the acceptance criteria and the results using IC3. It shows that IC3 satisfies all three criteria for this test suite.

Table 1: Acceptance Criteria for IECC Code Reference Home Auto-Generation Test Cases 1-4 and Corresponding Results from IC3

Reference Home Building Component	Test 1	Results	Test 2	Results	Test 3	Results	Test 4	Results
Above-grade walls (U_o)	0.082	0.082	0.082	0.082	0.082	0.082	0.060	0.060
Above-grade wall solar absorptance (α)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Above-grade wall infrared emittance (ε)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Basement walls (U_o)	n/a	n/a	n/a	n/a	n/a	n/a	0.059	0.059
Above-grade floors (U_o)	0.047	0.047	0.047	0.047	n/a	n/a	n/a	n/a
Slab insulation R-Value	n/a	n/a	n/a	n/a	0	0	0	0
Ceilings (U_o)	0.030	0.030	0.035	0.035	0.035	0.035	0.030	0.030
Roof solar absorptance (α)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Roof infrared emittance (ε)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Attic vent area* (ft^2)	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13
Crawlspace vent area* (ft^2)	n/a	n/a	10.26	10.26	n/a	n/a	n/a	n/a
Exposed masonry floor area * (ft^2)	n/a	n/a	n/a	n/a	307.8	307.80	307.8	307.8
Carpet & pad R-Value	n/a	2.0	n/a	2.0	2.0	2.0	2.0	2.0
Door Area (ft^2)	40	40	40	40	40	40	40	40
Door U-Factor	0.40	0.40	0.65	0.65	1.20	1.20	0.35	0.35
North window area* (ft^2) IECC 2004	69.26	69.26	69.26	69.26	69.26	69.26	102.63	102.64
(IECC 2006)	(67.50)	67.50	(67.50)	67.50	(67.50)	67.50	(67.50)	(67.50)
South window area* (ft^2) IECC 2004	69.26	69.26	69.26	69.26	69.26	69.26	102.63	102.64
(IECC 2006)	(67.50)	67.50	(67.50)	67.50	(67.50)	67.50	(67.50)	(67.50)
East window area* (ft^2) IECC 2004	69.26	69.26	69.26	69.26	69.26	69.26	102.63	102.64
(IECC 2006)	(67.50)	67.50	(67.50)	67.50	(67.50)	67.50	(67.50)	(67.50)
West window area* (ft^2) IECC 2004	69.26	69.26	69.26	69.26	69.26	69.26	102.63	102.64
(IECC 2006)	(67.50)	67.50	(67.50)	67.50	(67.50)	67.50	(67.50)	(67.50)
Window U-Factor	0.4	0.4	0.65	0.65	1.2	1.2	0.35	0.35
Window $SHGC_o$ (heating)	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340
Window $SHGC_o$ (cooling)	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280
SLA_o* (ft^2/ft^2) IECC 2004	0.00048	0.00048	0.00048	0.00048	0.00048	0.00048	0.00048	0.00048
(IECC 2006)	(0.00036)	0.00036	(0.00036)	0.00036	(0.00036)	0.00036	(0.00036)	0.00036
Internal gains* (Btu/day)	66,840	66,840	66,840	66,840	62,736	62,736	107,572	107,572
Labeled heating system rating	0.78 AFUE	0.78 AFUE	HSPF = 7.7	7.7 HSPF	HSPF = 7.7	7.7 HSPF	0.78 AFUE	0.78 AFUE
Labeled cooling system rating	SEER = 13	SEER = 13	SEER = 13	SEER = 13	SEER = 13	SEER = 13	SEER = 13	SEER = 13
Air Distribution System Efficiency	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Thermostat Type	Manual	Manual	Manual	Manual	Manual	Manual	Manual	Manual
Heating thermostat settings	68 F (all hours)	68F	68 F (all hours)	68F	68 F (all hours)	68F	68 F (all hours)	68F
Cooling thermostat settings	78 F (all hours)	78F	78 F (all hours)	78F	78 F (all hours)	78F	78 F (all hours)	78F
e-Ratio	-	**1.000**	-	**1.000**	-	**1.000**	-	**1.000**

2.3. HVAC Tests

The HVAC test suite includes two sets of test cases: 1) Test Suite 1: for air-conditioning systems, using Las Vegas, NV as the building location, and 2) Test Suite 2: for heating systems, using Colorado Springs, CO as the building location. Table 2 lists the test specifications for all test cases. All tests are to be performed using the HERS BESTEST Case L100, and assume zero duct leakage and all ducts and air handlers are in conditioned space. For these tests, the tool must be capable of generating HVAC results using, at a minimum, system type and efficiency as inputs. Figure 3 shows the acceptable ranges of percent change for heating/cooling energy use and IC3 results. All IC3 results fall within the acceptable limits.

Table 2: HVAC Test Specifications

| Test #	System Type	Capacity	Efficiency
Test Suite 1 – Air conditioning Systems (Location: Las Vegas, NV)			
HVAC1a (Base case)	Air cooled air conditioner	38.3 kBtu/h	SEER = 10
HVAC1b			SEER = 13
Test Suite 2 – Heating Systems (Location: Colorado Springs, CO)			
HVAC2a (Base case)	Gas Furnace	56.1 kBtu/h	AFUE = 78%
HVAC2b			AFUE = 90%
HVAC2c (Base case)	Air Source Heat Pump		HSPF = 6.8
HVAC2d			HSPF = 9.85
HVAC2e	Electric Furnace		COP = 1
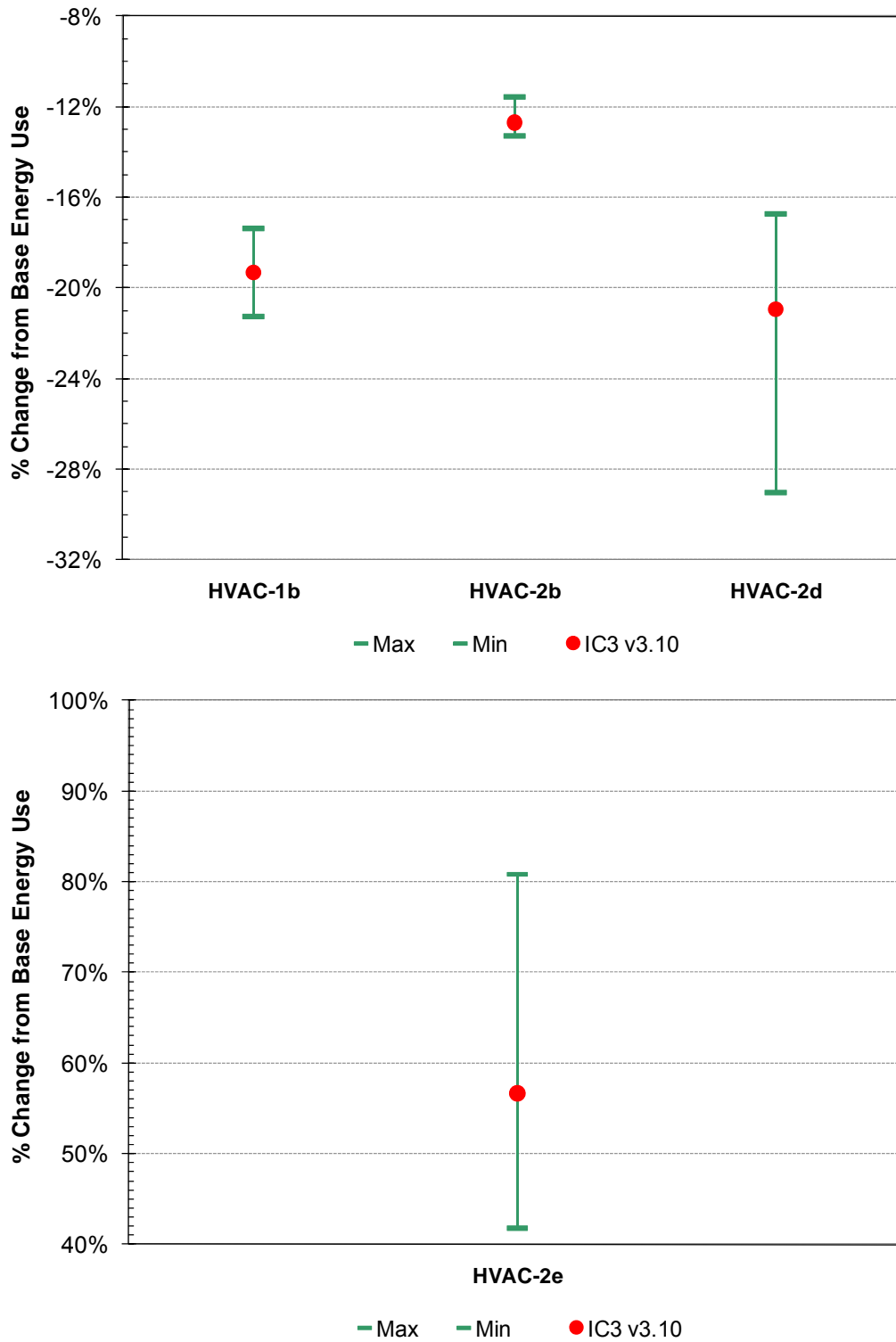
Figure 3: Percent Heating/Cooling Energy Use Change Using IC3 for HVAC Test Cases

2.4. Duct Distribution System Efficiency (DSE) Tests

The Duct Distribution System Efficiency (DSE) test suite includes two sets of test cases: 1) Heating Comparison Test Cases: these test cases use the HERS BESTEST Case L322 configured with an unconditioned basement with R-11 insulation and a 13% framing fraction in the floor joists of the main floor, and no basement wall insulation; and 2) Cooling Comparison Test Cases: these test cases use the HERS BESTEST Case L100.

Table 3 lists the test case-specific input parameters, which include system capacity, duct location, duct leakage, and duct R-value. All tests assume a 78% AFUE natural gas forced air furnace and a SEER 10 forced air cooling system. The system capacities are modified as shown in Table 3. The coil air flow is altered accordingly using a value of 360 cfm/ton of capacity. For all tests, the supply duct area is 20% of the conditioned floor area and the return duct area is 5% of the conditioned floor area. The duct leakage is modeled as specified in Table 3, with the supply and return leakage fractions set at 50%. The supply and return duct insulation of R-1.5 and R-7 is used for uninsulated (R=0) and insulated (R=6) ducts, respectively, to take into account the air-film-resistance.

Figure 4 shows the bounds criteria for these tests and the test results using IC3. It shows that IC3 results are within the acceptable ranges for all test cases. For cooling comparison test cases with ducts location in the attic, the IC3 results are close to the lower bound.

Table 3: DSE Test Specifications

| Test #	System Capacity	Duct Location	Duct Leakage	Duct R-value
Heating Comparison Test Cases (Location: Colorado Springs, CO)				
HVAC3a (Base case)	46.6 kBtu/h	100% conditioned	None	R-0
HVAC3b	56.0 kBtu/h	100% in basement	None	R-0
HVAC3c	49.0 kBtu/h	100% in basement	None	R-6
HVAC3d	61.0 kBtu/h	100% in basement	250 cfm_{25}	R-6
Cooling Comparison Test Cases (Location: Las Vegas, NV)				
HVAC3e (Base case)	-38.4 kBtu/h	100% conditioned	None	R-0
HVAC3f	-49.9 kBtu/h	100% in attic	None	R-0
HVAC3g	-42.2 kBtu/h	100% in attic	None	R-6
HVAC3h	-55.0 kBtu/h	100% in attic	250 cfm_{25}	R-6
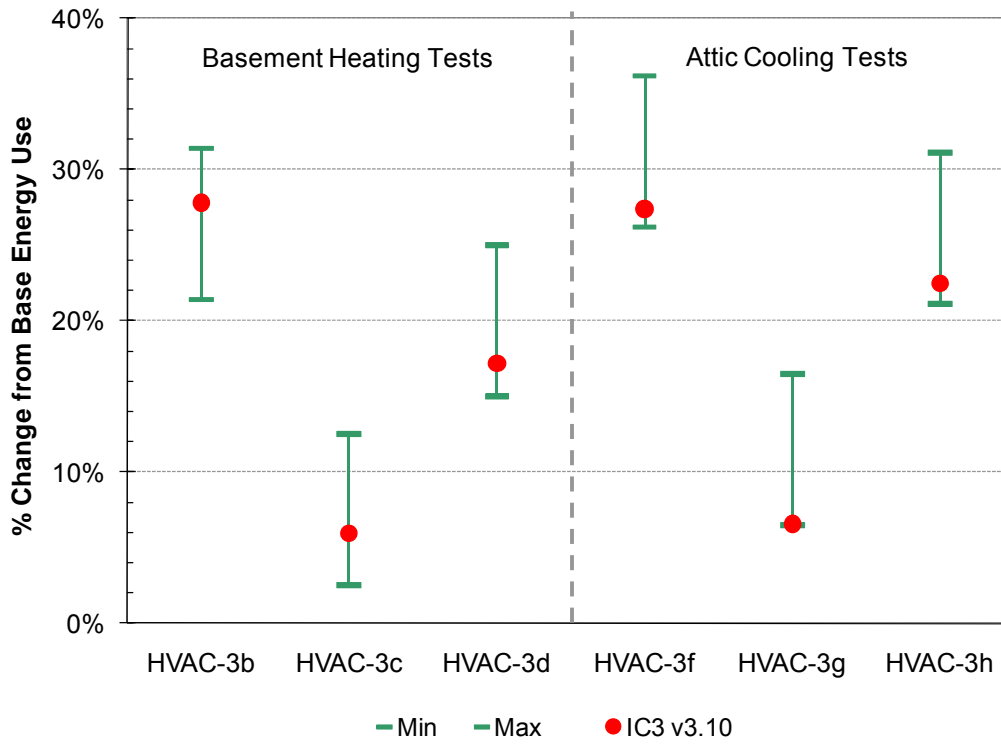
Figure 4: Percent Heating/Cooling Energy Use Change Using IC3 for DSE Test Cases

2.5. Hot Water System Performance Tests

The Hot Water System Performance test suite includes two sets of three tests for: a cold climate location, Duluth, MN and a hot climate location, Miami, FL.

Table 4 lists the test case-specific input parameters, which include: climate location, system efficiency and number of bedrooms. The test description also specifies that the hot water draw profile is obtained from ASHRAE Standard 90.2-2004, and cold-water inlet mains temperatures are calculated in accordance with NREL (2008). All tests are performed for a 40 gal. gas-fired domestic hot water system with 0.78 recovery efficiency and 40,000 Btu/hr burner capacities to supply hot water at 120 F°. The ambient temperature for the tank is at 75 F°.

The acceptance criteria and IC3 DHW test results are shown in Figure 5, which show difference metric (delta) and absolute metric (MMBtu), respectively. The delta metric is the % change in energy use for the alternative cases with respect to the base case, which is determined as follows:

*% Change = (alternative - base) / (base) * 100*

The absolute metric is the projected hot water energy use given in millions of Btu (site MMBtu). IC3 results are within acceptable limit for all cases.

Table 4: Hot Water System Performance Test Specifications

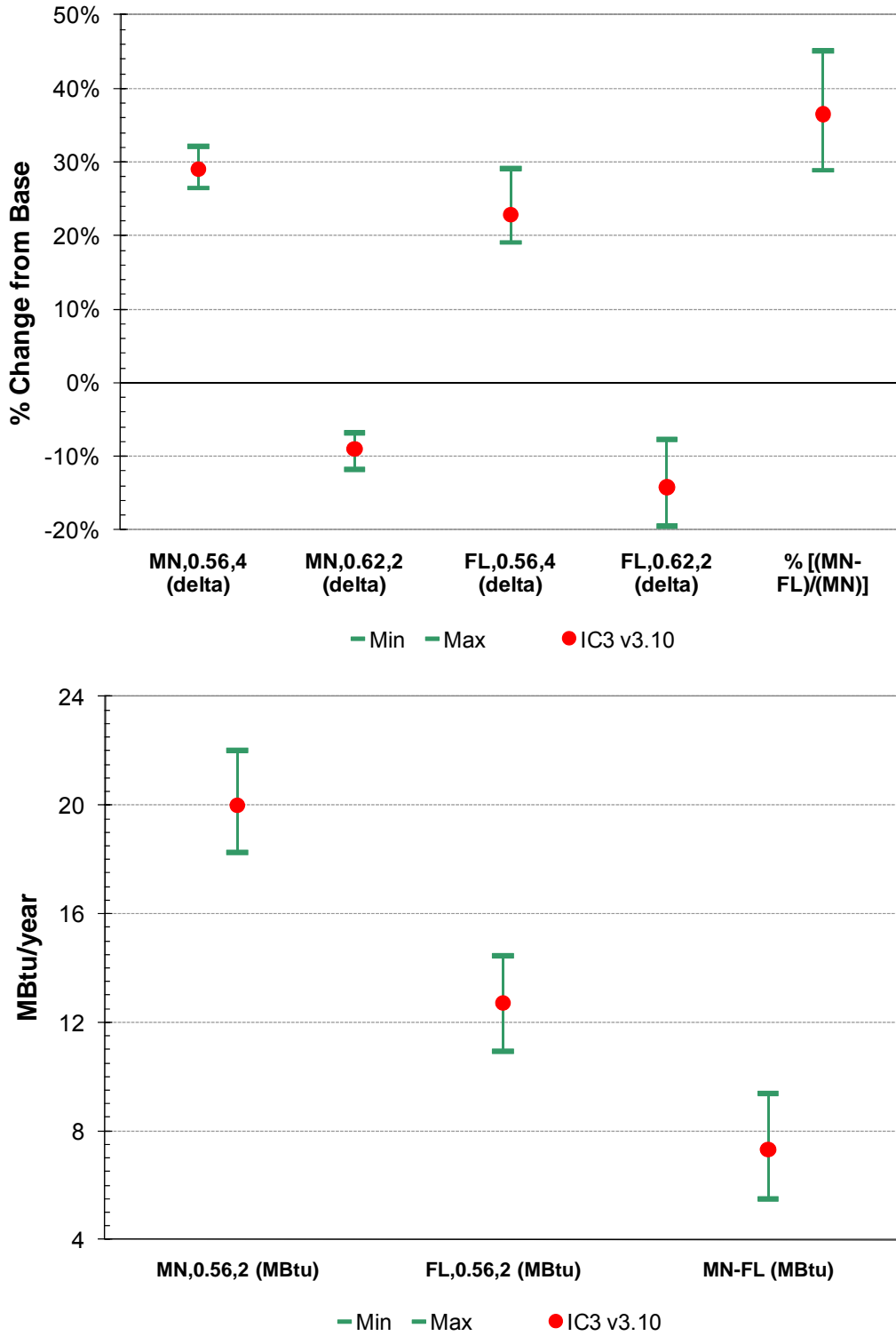| Test Case	Energy Factor	Number of Bedrooms	Location
DHW-MN-56-2 (Base case)	0.56	2	
DHW-MN-56-4	0.56	4	Duluth, MN
DHW-MN-62-2	0.62	2	
DHW-FL-56-2 (Base case)	0.56	2	
DHW-FL-56-4	0.56	4	Miami, FL
DHW-FL-62-2	0.62	2	

Figure 5: Percent Change in DHW Energy Use Using IC3 for Hot Water System Performance Test Cases

3. CONCLUSIONS

The ESL's web-based software tool IC3 v3.10 software has been tested using the RESNET verification procedures - RESNET Publication No. 07-003. The RESNET verification procedure is a set of verification tests that are required for RESNET accreditation of IECC performance compliance software tools. It consists of the five test suites: 1) Tier one of the HERS BESTEST; 2) IECC Code Reference Home auto-generation tests; 3) HVAC tests; 4) Duct distribution system efficiency tests; and 5) Hot water system performance tests.

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The results show that IC3 is a code-compliant simulation program that conforms to all acceptance criteria for all test suites of the RESNET verification procedures.

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