Evaluation of Auditor V1.0
By the
HERS BESTEST
Software Simulation Testing Protocol

Prepared by:

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CONCLUSION

Auditor V1.0 "passes" the HERS BESTEST Tier 1 software evaluation because all of its projected load calculations fall within the reasonable range of results for the test cases as established by the three reference software programs. The results indicate that Auditor V1.0's physical modeling methodologies and calculations conform to industry best practices.

BACKGROUND

The HERS (Home Energy Rating System) BESTEST (Building Energy Simulation Test) is a verification procedure developed by the National Renewable Energy Laboratory (NREL) to determine the accuracy and effectiveness of the energy load prediction capability of energy use analysis software. Multiple versions of the BESTEST procedure have been developed and adapted for certifying different types of energy use analysis software. HERS BESTEST is used in this evaluation because it emphasizes the modeling of residential houses. Many utilities, home performance sponsors, utility commissions and state energy offices require that energy auditing software used in their residential energy efficiency programs has passed a third party certification protocol, which frequently includes the HERS BESTEST.

The validation methodology consists of comparative testing – in which results from software programs are compared to results from other software programs. The comparative approach includes both "sensitivity testing" and "intermodal comparisons". It uses a wide variety of building configurations and characteristics as test cases for the evaluation. The comparative procedure uses results from three widely used and well-validated, detailed building energy simulation software programs to develop a range of reasonable results for each of the test cases. The reference programs used to generate the test case results are:

1) BLAST 3.0, Level 215: Developed by the U.S. Department of Defense for use in analyzing energy efficiency improvements for their buildings.

2) DOE2.1E-W54: At the time of HERS BESTEST Development, DOE2.1E was considered to be the most advanced of the programs sponsored by the U.S. Department of Energy and the technical basis for setting national building energy codes and standards in the United States.

3) SERIRES/SUNCODE 5.7: SERIRES is a public domain program developed by NREL. SUNREL, the calculation engine behind the TREAT software, was developed as an upgrade to SERIRES.

The results from these three reference programs are then statistically analyzed to determine the 90% confidence interval for each set of test case results. These 90% confidence intervals establish the range of acceptable results for each test case. HERS BESTEST procedures describe two 'Tiers' of software test cases – Tier 1 and Tier 2. BESTEST Tier 1 tests consist of exercising the elements of a basic house with typical glazing and insulation. Specific Tier 1 tests are designed to test a program's ability produce energy consumption and savings results as described below.

BESTEST Tier 2 tests are more focused on testing a software program's ability to guide passive solar design, and are not addressed in this document.

Note: Software is considered to 'pass' a HERS BESTEST Tier if it passes ALL tests included within the Tier.

TEST CASES

The following Tier 1 test cases are provided by the HERS BESTEST procedure:

- **Case L100: The Base Case Building.** This is a 1539 sq.ft, single-story, wood-frame, and 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 are insulated with R-11 insulation and the ceiling and floor are insulated with R-19 insulation. This is the 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.
- **Case L110: High Infiltration (1.5 ach).** Exactly the same as Case L100 with the exception of the infiltration rate, which is increased from its base case value 0.67 air changes per hour (ach) to a value of 1.5 ach.
- **Case L120: Well Insulated Walls and Roof.** Exactly the same as Case L100 except that the wall insulation is increased from R-11 to R-23 and the ceiling insulation is increased from R-19 to R-58.
- **Case L130: Double-Pane, Low-Emissivity Windows with Wood Frames.** Exactly the same as Case L100 except that the single-glazed windows are replaced with high-efficiency windows having an overall U-factor of 0.30 and an overall Solar Heat Gain Coefficient (SHGC) of 0.335.

- **Case L140: Zero Window Area.** Exactly the same as Case L100 except that the windows are replaced with wood frame walls having R-11 insulation.
- **Case L150: South-Oriented Windows.** Exactly 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.** Exactly the same as Case L150 except that an opaque overhang is added at the top of the south facing exterior wall. The overhang extends outward 2.5 feet and is positioned 1 foot above the top of the 5-foot high windows.
- **Case L160: East- and West-Oriented Windows.** Exactly 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.** Exactly the same as Case L100 except that the internal gains are reduced from 68,261 Btu/day to zero.
- **Case L200: Energy Inefficient.** Exactly the same as Case L100 except for the following:
    - Infiltration rate is increased from 0.67 ach to 1.5 ach,
    - Exterior wall insulation is replaced by an air gap,
    - Crawlspace floor insulation is removed, and
    - Ceiling insulation is reduced from R-19 to R-11.
- **Case L202: Low Exterior Solar Absorbance.** Exactly the same as Case L100 except that the solar absorbance of the roof and walls is reduced from 0.6 to 0.2.
- **Case L302: Uninsulated Slab-on-Grade.** Exactly 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.** Exactly the same as Case L302 except that R-5.4 exterior foundation insulation is added around the slab perimeter.
- **Case L322: Uninsulated Basement.** Exactly the same as Case L100 except that the floor system is changed from a fully vented crawlspace to an uninsulated conditioned basement with 1-0" of the uninsulated basement wall and the uninsulated floor band joist exposed. This case is not used for cooling energy load results.
- **Case L324: Insulated Basement.** Exactly the same as Case L322 except that R-11 insulation is added at the inside of the basement walls and the floor band joist. This case is not used for cooling energy load results.

With the exception of Cases L322 and L324, each of the above test cases is simulated in Colorado Springs, CO to evaluate heating energy loads and in Las Vegas, NV to evaluate cooling energy loads.

Annual Heating Load Results for Colorado Springs, CO

Table 1 below consists of the 90% confidence intervals for the maximum and minimum ranges of allowable heating load predictions produced by the three reference programs compared against the heating load predictions of Auditor V1.0 in Colorado Springs, CO.

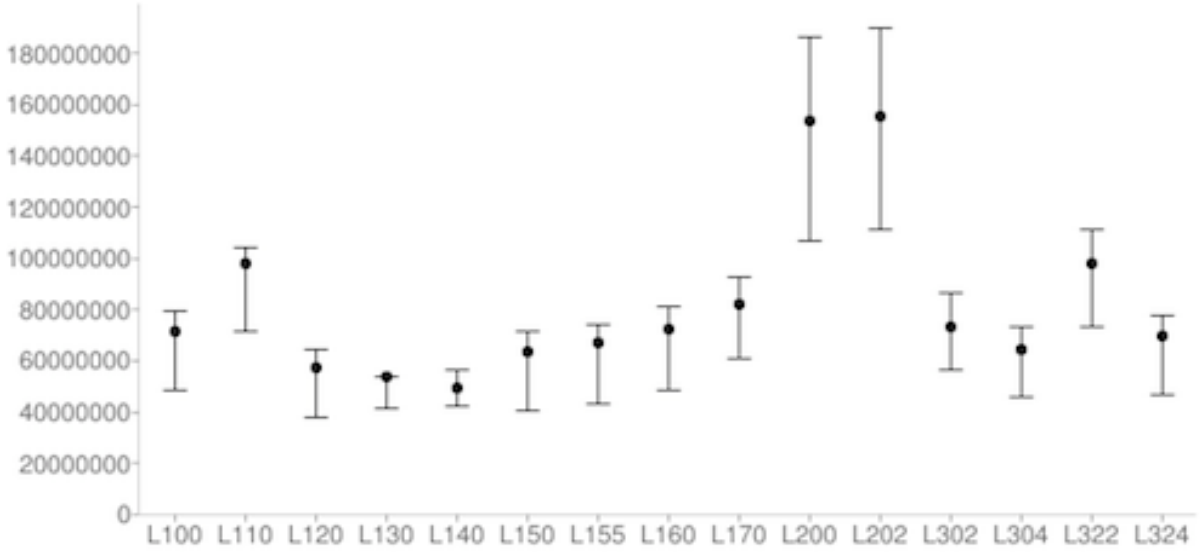
All Auditor V1.0 heating load results fall within the 90% confidence intervals required by national HERS standards

Table 1. Annual Heating Load Results for Colorado Springs, CO
(Million Btu's)

Test Case	Range Minimum	Auditor V1.0	Range Maximum	Result
L100	48.75	71.54	79.48	Pass
L110	71.88	97.84	103.99	Pass
L120	37.82	57.54	64.30	Pass
L130	41.82	53.75	53.98	Pass
L140	42.24	49.16	56.48	Pass
L150	40.95	63.98	71.33	Pass

L155	43.53	67.46	74.18	Pass
L160	48.78	72.67	81.00	Pass
L170	61.03	81.78	92.40	Pass
L200	106.41	155.63	185.87	Pass
L202	111.32	155.03	190.05	Pass
L302	56.12	73.48	86.90	Pass
L304	46.11	64.65	73.15	Pass
L322	73.71	98.42	111.69	Pass
L324	46.38	69.92	77.47	Pass

Figure 1a below is the graphic representation of the data contained in Table 1 above.



Annual Heating Load Differential Results for Colorado Springs, CO:

Table 2 below consists of the 90% confidence intervals for the maximum and minimum ranges of allowable heating load differential predictions produced by the three reference programs compared against the heating energy load differential predictions of Auditor V1.0 in Colorado Springs, CO.

All Auditor V1.0 heating load differential results fall within the 90% confidence intervals required by national HERS standards.

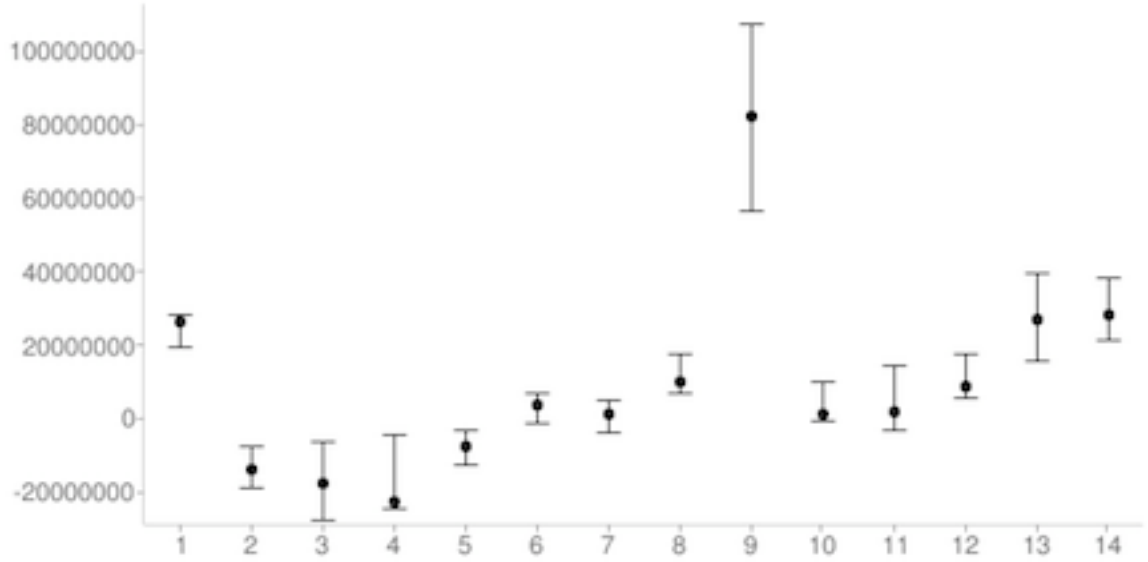
Table 2. Annual Heating Load Differential Results for Colorado Springs, CO

(Million Btu's)

Test Case	Range Minimum	Auditor V1.0	Range Maximum	Result
L110-L100 (1)	19.36	26.30	28.12	Pass
L120-L100 (2)	-18.57	-14.01	-7.67	Pass
L130-L100 (3)	-27.50	-17.79	-5.97	Pass
L140-L100 (4)	-24.42	-22.38	-4.56	Pass
L150-L100 (5)	-12.53	-7.56	-3.02	Pass
L155-L150 (6)	-1.54	3.48	6.88	Pass
L160-L100 (7)	-3.72	1.13	5.10	Pass
L170-L100 (8)	7.12	10.24	17.64	Pass
L200-L100 (9)	56.39	82.08	107.66	Pass
L202-L200 (10)	-0.51	1.40	9.94	Pass

L302-L100 (11)	-3.29	1.94	14.50	Pass
L302-L304 (12)	5.66	8.83	17.75	Pass
L322-L100 (13)	15.71	26.88	39.29	Pass
L322-L324 (14)	21.25	28.50	38.22	Pass

Figure 2a below is the graphic representation of the data contained in Table 2 above.



Annual Cooling Load Results for Las Vegas, NV

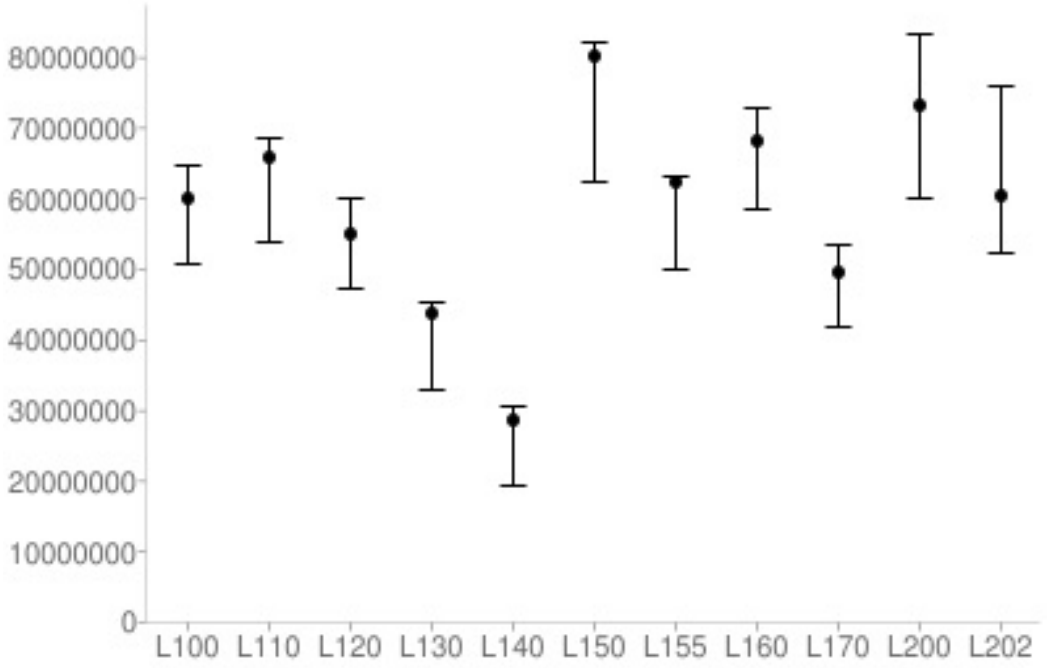
Table 3 below consists of the 90% confidence intervals for the maximum and minimum ranges of allowable cooing load predictions produced by the three reference programs compared against the cooling energy load predictions of Auditor V1.0 in Las Vegas, NV.

All Auditor V1.0 cooling load results fall within the 90% confidence intervals required by national HERS standards.

Table 3. Annual Cooling Load Results for Las Vegas, NV
(Million Btu's)

Test Case	Range Minimum	Auditor V1.0	Range Maximum	Result
L100	50.66	59.91	64.88	Pass
L110	53.70	65.70	68.50	Pass
L120	47.34	55.15	60.14	Pass
L130	32.95	43.81	45.26	Pass
L140	19.52	28.51	30.54	Pass
L150	62.41	80.36	82.33	Pass
L155	50.08	62.34	63.06	Pass
L160	58.61	68.35	72.99	Pass
L170	41.83	49.67	53.31	Pass
L200	60.25	73.07	83.43	Pass
L202	52.32	60.38	75.96	Pass

Figure 3a below is the graphic representation of the data contained in Table 3 above.



Cooling Load Differential Results

Table 4 below consists of the 90% confidence intervals for the maximum and minimum ranges of allowable cooling load differential predictions produced by the three reference programs compared against the cooling energy load differential predictions of Auditor V1.0 in Las Vegas, NV.

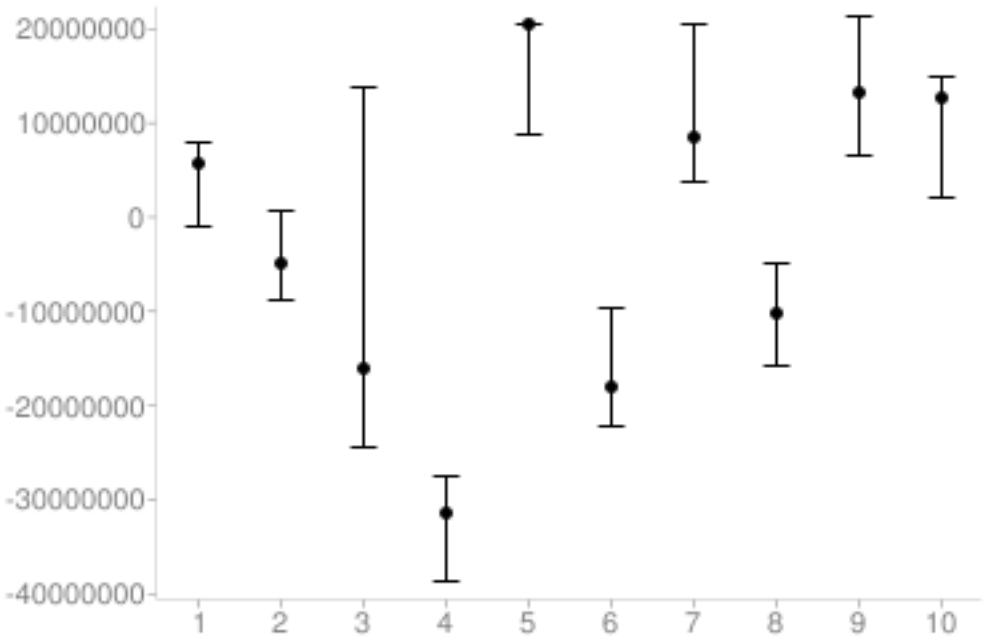
All Auditor V1.0 cooling load differential results fall within the 90% confidence intervals required by national HERS standards.

Table 4. Annual Cooling Load Differential Results for Las Vegas, NV

(Million Btu's)

Test Case	Range Minimum	Auditor V1.0	Range Maximum	Result
L110-L100 (1)	-0.98	5.79	7.84	Pass
L120-L100 (2)	-8.87	-4.77	0.68	Pass
L130-L100 (3)	-24.40	-16.11	-13.71	Pass
L140-L100 (4)	-38.68	-31.40	-27.44	Pass
L150-L100 (5)	8.72	20.45	20.55	Pass
L155-L150 (6)	-22.29	-18.02	-9.64	Pass
L160-L100 (7)	3.88	8.44	12.28	Pass
L170-L100 (8)	-15.74	-10.24	-4.83	Pass
L200-L100 (9)	6.63	13.16	21.39	Pass
L200-L202 (10)	2.03	12.69	14.86	Pass

Figure 4a below is the graphic representation of the data contained in **Table 4** above.



References

1. Judkoff, R. and J. Neymark, 1995. "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST)," Vol. 1 and 2, Report No. NREL/TP-472-7332. National Renewable Energy Laboratory, Golden, Colorado 80401-3393 (Online at http://www.nrel.gov/docs/legosti/fy96/7332a.pdf)