Procedures for Certifying Residential Energy Efficiency Tax Credits

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1. Purpose

This publication provides procedures for certifying residential energy efficiency tax incentives, including the certification of verification professionals and the verification and accreditation of software tools used for calculating home energy savings for the certification of highly efficient new homes for federal tax credits and for the certification of energy savings resulting from improvements to existing homes through home energy retrofits.

2. Scope

This procedure applies to the certification of residential energy savings for tax incentive qualification for all new and existing single family dwellings and all new and existing multifamily dwellings that are three stories or less above grade level. This procedure employs a set of standard operating conditions representative of typical residences. As such, it may not accurately reflect the energy use of residences that depart from these standard operating conditions. This procedure does not apply to multifamily dwellings that are greater than three stories above grade.

3. Procedures for Certification of Eligibility for Tax Credits

3.1 Standard for Inspection of Homes

To be eligible for the federal tax credits for homes every home shall be independently field tested to verify the energy performance of the home. To comply with the law, field verification of a qualifying home's energy performance shall be conducted in accordance with the *Mortgage Industry National Home Energy Rating System Standards*. These standards are posted online at http://www.resnet.us/standards/mortgage.

3.2 Procedures for Certifying Individuals

Individuals authorized to certify a home's qualification for tax credits must be trained and certified in accordance with the procedures contained in the *Mortgage Industry National Home Energy Rating System Standards*.

4. Procedures for Verification of Software Programs

4.1 New Homes

Since the credits for new homes are based on performance as compared with Section 404 of the 2006 IECC, computer software modeling is required. In order to ensure the accuracy of computer tools, software programs seeking accreditation as tax credit qualification tools shall comply with Sections 4.1.1 and 4.1.2.

4.1.1 Reference Home Rule Set. The technical specifications defined in Appendix A of this document shall serve as the rule set for configuration of the Reference and Qualifying Homes for determination of tax credit qualification.

4.1.2 Suite of Software Verification Tests. RESNET has defined a series of software test suites that shall be used to verify the accuracy of software programs for tax credit computation. To become accredited as a New Home Tax Credit qualification tool, software shall be subjected to verification testing in accordance with Sections 4.1.2.1 through 4.1.2.4.

4.1.2.1 **ANSI/ASHRAE Standard 140-2011, Class II, Tier 1 Tests.** ASHRAE Standard 140, Class II Tests were developed from the HERS BESTEST[1] for testing the accuracy of simulation software for predicting building loads. The ANSI/ASHRAE Standard 140-2011, Class II, Tier 1 test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited. Acceptance criteria for this suite of tests shall be as specified in Appendix B.

4.1.2.2 <u>Auto-generation of the Reference Home</u> – This test verifies the ability of the software tool to automatically generate the tax credit Reference Home. See Appendix C for the test cases and acceptance criteria for the auto-generation test suite.

4.1.2.3 <u>RESNET HVAC Tests</u> – RESNET has developed a series of tests that test the consistency with which software tools treat HVAC equipment, including furnaces, air conditioners, and air source heat pumps. See Appendix D for the test cases and the established acceptance criteria for this test suite.

4.1.2.4 <u>Duct Distribution System Efficiency Tests</u> – This test measures the accuracy with which software tools calculate air distribution system losses. ASHRAE Standard 152 results are used as the basis for the test suite acceptance criteria. See Appendix E for the test cases and acceptance criteria for this test suite.

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

4.2 Existing Homes

Energy improvements to existing homes shall be based on the projected change in whole-home energy use attributable to the installed energy improvements considering all standard energy end uses in the existing home.

4.2.1 Software Accreditation. Since the original configuration of the home serves as the baseline for this energy use comparison, there is no requirement for the Reference Home auto-generation test suite as is required for new homes. However, because the comparison is based on all of the energy end uses of the home, there are additional software verification and accreditation requirements. To become accredited as an Existing Home Tax Credit qualification tool, software shall be subjected to verification testing in accordance with Sections 4.2.1.1 through 4.2.1.4.

4.2.1.1 ANSI/ASHRAE Standard 140-2011, Class II, Tier 1 Tests. ASHRAE Standard 140, Class II Tests were developed from the HERS BESTEST for testing the accuracy of simulation software for predicting building loads. The ANSI/ASHRAE Standard 140, Class II, Tier 1 test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited. Acceptance criteria for this suite of tests shall be as specified in Appendix B.

In addition to the Tier One HERS BESTEST, one additional test case shall be required for verification and accreditation of software for existing homes. This test case is a combination of HERS BESTEST cases L120A and L130A and has been named case L125A. See Appendix G for the specifications for this test case and for the established acceptance criteria for this test case.

4.2.1.2 <u>RESNET HVAC Tests</u> **–** RESNET has developed a series of tests that test the consistency with which software tools treat HVAC equipment, including furnaces, air conditioners, and air source heat pumps. See Appendix C for the test cases and the established acceptance criteria for this test suite.

4.2.1.3 <u>Duct Distribution System Efficiency Tests</u> **–** This test measures the accuracy with which software tools calculate air distribution system losses. ASHRAE Standard 152 results are used as the basis for the test suite acceptance criteria. See Appendix D for the test cases and acceptance criteria for this test suite.

4.2.1.4 <u>Service Hot Water System Tests</u> **–** This test measures the accuracy with which software tools calculate the hot water use in dwellings as a function of the entering water temperature, the daily hot water use and the labeled efficiency of the service hot water system. See Appendix E for the test cases and the established acceptance criteria for this test suite.

4.2.2 Energy Savings Determination. Energy savings for existing home retrofits shall be determined by comparing a Baseline Home with an Improved Home in accordance with Sections 4.2.2.1 through 4.2.2.4.

4.2.2.1 Baseline Home. The Baseline Home model for the purposes of determining the energy savings of an existing home retrofit shall be the original configuration of the existing home, including the full complement of lighting, appliances and residual miscellaneous energy use as specified by Tables 303.4.1.7.1(1) and 303.4.1.7.1(2) of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011. The energy use of these end uses in the Baseline Home shall be based on the original home configuration following the provision of Section 303.4.1.7.2 of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011.

4.2.2.1.1 Where multiple appliances of the same type exist in the original configuration of the existing home, the same number of those appliance types shall be included in the Baseline Home model.

4.2.2.1.2 Where a standard appliance as defined by Tables 303.4.1.7.1(1) and 303.4.1.7.1(2) of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011, does not exist in the original configuration of the existing home, the standard default energy use and internal gains as specified by Table 303.4.1(3) of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011, for that appliance shall be included in the Baseline Home model.

4.2.2.2 Improved Home. The improved home model for the purpose of determining the energy savings of an existing home retrofit shall be the existing home's configuration including all energy improvements to the original home and including the full complement of lighting, appliances and residual miscellaneous energy use contained in the home after all energy improvements have been implemented.

4.2.2.2.1 Where an appliance has been upgraded but the existing appliance is not removed from the existing home property, both the new and existing appliance shall be included in the Improved Home model.[2]

4.2.2.2.2 Where a standard appliance as defined by Tables 303.4.1.7.1(1) and 303.4.1.7.1(2) of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011, does not exist in the improved configuration of the existing home, the standard default energy use and internal gains as specified by Table 303.4.1(3) of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011, for that appliance shall be included in the Improved Home model.

4.2.2.2.3 Improvements in lighting and appliance energy use in the Improved Home model shall be calculated in accordance with Section 303.4.1.7.2 of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011.

[2] For example, if a refrigerator is upgraded to a more efficient model and the original refrigerator is kept on property for potential use as a second refrigerator; both refrigerators shall be included in the Improved Home energy model.

4.2.2.3 Standard Operating Conditions.

4.2.2.3.1 Both the Baseline Home and Improved Home shall be configured and modeled in accordance with the Qualifying Home specifications of Appendix A except that the Baseline Home shall not violate the input constraints specified in Table 4.2.2.3(1) below.

Table 4.2.2.3(1) Baseline Home Input Constraints

Equipment Constraints*	**Min Value**
Forced-air furnace, AFUE	72%
Hot water / steam boiler, AFUE	60%
Heat Pump, HSPF	6.5
Heat Pump, SEER	9.0
Central air conditioner, SEER	9.0
Room air conditioner, EER	8.0
Gas-fired storage water heater, EF	0.50
Oil-fired storage water heater, EF	0.45
Electric storage water heater, EF	0.86
Enclosure Constraints (including air film conductances)	**Max U-factor**
Wood-frame wall	0.222
Masonry wall	0.250
Wood-frame ceiling with attic (interior to attic space)	0.286
Unfinished roof	0.400
Wood-frame floor	0.222
Single-pane window, wood frame	0.714
Single-pane window, metal frame	0.833

* **Exception:** Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.

4.2.2.3.2 Air Distribution Systems

4.2.2.3.2.1 In cases where the air distribution system leakage is not measured in the original Baseline Home, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled in both the Baseline Home and the Improved Home as 0.10 times the conditioned floor area of the home split equally between the supply and return side of the air distribution system with the leakage distributed evenly across the duct system.

Exception: If the air handler unit and a minimum of 75% of its duct system are entirely inside the conditioned space boundary, the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled in both the Baseline Home and the Improved Home as 0.05 times the conditioned floor area of the home split equally between the supply and return side of the air distribution system with the leakage distributed evenly across the duct system.

4.2.2.3.2.2 In cases where the air distribution system leakage is measured in the Baseline Home, the following shall apply:

4.2.2.3.2.2.1 For the Baseline Home, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be modeled as the lesser of the measured air distribution system leakage to outdoors at 25 Pascal pressure difference in the original Baseline Home or 0.24 times the conditioned floor area of the home, either split evenly between the supply and return side of the air distribution system or as measured separately with the leakage distributed evenly across the duct system.

4.2.2.3.2.2.2 For the Improved Home, the ducts shall be modeled in the spaces in which they are located and the air distribution system leakage to outdoors at 25 Pascal pressure difference shall be set equal to the measured air distribution system leakage to outdoors at 25 Pascal pressure difference in the Improved Home, either split evenly between the supply or return side of the air distribution system or as measured separately with the leakage distributed evenly across the duct system.

4.2.2.3.2 Both the Baseline Home and the Improved Home shall be subjected to the operating conditions specified by Section 303.5.1.4.2 of the *Mortgage Industry National Home Energy Rating Systems Standards*, effective November 15, 2011.

4.2.2.4 Total Energy Savings Calculation.

4.2.2.4.1 Energy units used in the calculation of energy savings shall be units of Equivalent Electric Energy using the Reference Electricity Production Efficiency for fossil fuels. Equivalent electric energy use shall be calculated using Equation 4.2.2.4-1, below.

$$\mathrm{kWh_{eq}} = \mathrm{kWh_{elec}} + \frac{\mathrm{Btu_{fossil}}{*}0.40}{3412} \qquad \text{(Eqn. 4.2.2.4-1)}$$

4.2.2.4.2 Energy savings shall be calculated as the difference between the whole-house projected equivalent electric energy use of the Baseline Home and the whole-house projected equivalent electric energy use of the Improved Home.

4.2.2.4.3 The energy savings percentage of the retrofit shall be calculated as the whole-house equivalent electric energy savings as determined by clause 4.2.2.4.2 above divided by the whole-house equivalent electric energy use of the Baseline Home.

4.3 Process for Accrediting Software Programs

In states that have laws regulating home energy rating software tools and required procedures for verification of software tools used for energy codes, the state may add additional state requirements to these national requirements.

The RESNET accreditation process provides a suite of verification tests to certify that rating software tools conform to the verification criteria for each test. The software developer shall be required to submit the test results, test runs, and the software program with which the tests were conducted to RESNET. This information may be released by RESNET for review by any party, including the Treasury Department and competing software developers. This process is expected to result in compliance without a costly bureaucratic review and approval process.

4.4 Process for Software Developers to Apply to if Their Programs Cannot Meet the Test Verification Requirements

RESNET has established an appeals process that software developers may use if their software or tax credit qualification programs are so unique that they cannot be accurately tested through the RESNET software testing procedures. The elements of this appeal process are:

- The provider's documentation of how the software or qualification program meets or exceeds the criteria established in the RESNET procedures for tax credit qualification.
- The software developer's justification and documentation as to why the software or qualification program is so unique that it cannot comply with the RESNET testing protocols.
- Independent evaluation of the software tool or qualification program by RESNET in collaboration with independent individuals with appropriate expertise. Based upon the results of the evaluation, RESNET may certify that the software tool or qualification program meets or exceeds the performance criteria of RESNET's procedures for tax credit qualification programs.

4.5 References

ASHRAE, Standard 152-2004, "Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distributions Systems." American Society for Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ASHRAE Standard 140-2011, "Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs." American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA, 2012.

ASTM Standard C-1549-2009, "Standard Test Method for Determining Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer," ASTM International, West Conshohocken, PA.

ASTM Standard E-1918-2006, “Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.” ASTM International, West Conshohocken, PA.

ASTM C1371 - 04a(2010)e1, “Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers.” ASTM International, West Conshohocken, PA.

CRRC-1, 2008. “Method #1: Standard Practice for Measuring Solar Reflectance of a Flat, Opaque, and Heterogeneous Surface Using a Portable Solar Reflectometer.” Cool Roof Rating Council, Oakland, CA.

ICC, 2006, “2006 International Energy Conservation Code.” International Code Council, 500 New Jersey Avenue, NW, Washington, DC.

RESNET, January 2013, *Mortgage Industry National Home Energy Rating System Standards*. Residential Energy Services Network, Oceanside, CA.

Appendix A

Proposed Software Tool Certification and Rule Set Standard For New Home Federal Tax Incentive Qualification

Introduction

This proposed software tool certification and rule set standard consists of three principal sections: Section 1 provides recommended standards for the certification of software tools used for tax credit qualification; Section 2 specifies the method by which energy savings are determined; and Section 3 (the "rule set") provides recommended standards for the configuration, simulation, analysis and testing (where applicable), of the Reference Home and the Qualifying Home.

1 Software Tools for Tax Incentive Qualification

1.1 Minimum software tool capabilities. Calculation procedures used to qualify homes for tax incentives shall be computer-based software tools capable of calculating the annual energy consumption of all building elements that differ between the Reference Home and the Qualifying Home and shall include the following minimum capabilities:

1. Computer generation of the Reference Home using only the input for the Qualifying Home. The calculation procedure shall not allow the user to directly modify the building component characteristics of the Reference Home.
2. Calculation of whole-building, single-zone sizing for the heating and cooling equipment in the Reference Home in accordance with ASHRAE *Handbook of Fundamentals* or equivalent computational procedures.
3. Calculations that account for the indoor and outdoor temperature dependencies and the part load performance of heating, ventilating and air conditioning equipment based on climate and equipment sizing.
4. Listing of each of the Qualifying Home component characteristics determined by the analysis to provide qualification along with their respective performance rating (e.g. R-Value, U-Factor, SHGC, HSPF, AFUE, SEER, EF, etc.).

1.2 Minimum reporting requirements. Tax incentive qualification software tools shall generate reports that, at a minimum, document the following information:

a. Address of the Qualifying Home;
b. Documentation of all building component characteristics of the Qualifying Home . Such documentation shall also give the estimated annual energy

consumption for heating and cooling for both the Reference Home and the Qualifying Home;

c. Name and signature of individual certified to complete the qualification report;

d. Name and version of the certified tax credit qualification software tool used to perform the qualification analysis.

1.3 Software tool certification. Tools approved by RESNET shall be based on verification for certification in accordance with Sections 1.3.1 through 1.3.4.

1.3.1 ANSI/ASHRAE Standard 140, Class II, Tier 1 Tests. ASHRAE Standard 140, Class II Tests were developed from the HERS BESTEST[3] for testing the accuracy of simulation software for predicting building loads. The ANSI/ASHRAE Standard 140, Class II, Tier 1 test procedure has been adopted by RESNET and is a requirement for all software programs to be accredited. Acceptance criteria for this test suite shall be as specified in Appendix B.

1.3.2 Reference Home Auto-generation Tests. This test suite determines the ability of software tools to automatically generate the tax credit Reference Home. Verification criteria shall be as specified in Appendix C of this publication.

1.3.3 RESNET HVAC Tests. This test suite determines the ability of software tools to account for indoor and outdoor temperature dependencies and the part load performance of heating, ventilating and air conditioning equipment based on climate. Verification criteria shall be as specified in Appendix D of this publication.

1.3.4 Distribution System Efficiency (DSE) Tests. This test suite determines the ability of software tools to account for air distribution system losses. Verification criteria shall be as specified in Appendix E of this publication.

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

2 Computation of Energy Savings

2.1 The energy loads for heating and cooling in the Qualifying Home shall be normalized to account for the differences in improvement potential that exist across equipment types using the following formula:[4]

nMEUL = REUL * (nEC_x /EC_r)

where:

nMEUL = normalized Modified End Use Loads (for heating or cooling) as computed using accredited simulation tools.
REUL = Reference Home End Use Loads (for heating or cooling) as computed using accredited simulation tools.
EC_r = estimated Energy Consumption for Reference Home's end uses (for heating, including auxiliary electric consumption, or cooling) as computed using accredited simulation tools.

and where:

nEC_x = (a* EEC_x – b)*(EC_x * EC_r * DSE_r) / (EEC_x * REUL)

where:

nEC_x = normalized Energy Consumption for Qualifying Home's end uses (for heating, including auxiliary electric consumption, or cooling) as computed using accredited simulation tools.
EC_r = estimated Energy Consumption for Reference Home's end uses (for heating, including auxiliary electric consumption, or cooling) as computed using accredited simulation tools.
EC_x = estimated Energy Consumption for the Qualifying Home's end uses (for heating, including auxiliary electric consumption, or cooling) as computed using accredited simulation tools.
EEC_x = Equipment Efficiency Coefficient for the Qualifying Home's equipment, such that
EEC_x equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that
    EEC_x equals 1.0 / MEPR for AFUE or COP ratings, or such that
    EEC_x equals 3.413 / MEPR for HSPF, EER or SEER ratings.
DSE_r = REUL/EC_r * EEC_r

[4] Source: Fairey, P., J. Tait, D. Goldstein, D. Tracey, M. Holtz, and R. Judkoff, "The HERS Rating Method and the Derivation of the Normalized Modified Loads Method." Research Report No. FSEC-RR-54-00, Florida Solar Energy Center, Cocoa, FL, October 11, 2000. Available online at: http://www.fsec.ucf.edu/bldg/pubs/hers_meth/

For simplified system performance methods, DSE_r equals 0.80 for heating and cooling systems. However, for detailed modeling of heating and cooling systems, DSE_r may be less than 0.80 as a result of part load performance degradation, coil air flow degradation, improper system charge and auxiliary resistance heating for heat pumps. Except as otherwise provided by these Standards, where detailed systems modeling is employed, it must be applied equally to both the Reference and the Qualifying Homes.

EEC_r = Equipment Efficiency Coefficient for the Reference Home's equipment, such that EEC_r equals the energy consumption per unit load in like units as the load, and as derived from the Manufacturer's Equipment Performance Rating (MEPR) such that

EEC_r equals 1.0 / MEPR for AFUE or COP ratings, or such that

EEC_r equals 3.413 / MEPR for HSPF, EER or SEER ratings.

REUL = Reference Home End Use Loads (for heating or cooling) as computed using accredited simulation tools.

and where the coefficients 'a' and 'b' are as defined by Table 2.1 below:

Table 2.1. Coefficients 'a' and 'b'

Fuel type and End Use	a	b
Electric space heating	2.2561	0
Fossil fuel* space heating	1.0943	0.4030
Biomass space heating	0.8850	0.4047
Electric air conditioning	3.8090	0
Electric water heating	0.9200	0
Fossil fuel* water heating	1.1877	1.0130

*Such as natural gas, LP, fuel oil

2.2 Following normalization of the heating and cooling energy consumptions for the Qualifying Home as specified in section 2.1 above, the Reference Home's total reference end use loads for heating and cooling (REULtot) shall be compared with the Qualifying Home's total normalized modified end use loads for heating and cooling (nMEULtot) using the following formula to determine the % Energy Reduction:

% Energy Reduction = [(REULtot – nMEULtot) / (REULtot)] * 100

3 Rule Set for Configuration of the Reference Home and Qualifying Homes

3.1 General. Except as specified by this Section, the Reference Home and Qualifying Home shall be configured and analyzed using identical methods and techniques.

3.2 Residence Specifications. The Reference Home and Qualifying Home shall be configured and analyzed as specified by Table 3.2(1).

Table 3.2(1) Specifications for the Reference and Qualifying Homes

Building Component	**Reference Home**	**Qualifying Home**
Above-grade walls:	Type: wood frame Gross area: same as Qualifying Home U-Factor: from Table 3.2(2) Solar absorptance = 0.75 Emittance = 0.90	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home
Conditioned basement walls:	Type: same as Qualifying Home Gross area: same as Qualifying Home U-Factor: from Table 3.2(2) with the insulation layer on the interior side of walls	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home
Floors over unconditioned spaces:	Type: wood frame Gross area: same as Qualifying Home U-Factor: from Table 3.2(2)	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home
Crawlspaces:	Type: vented with net free vent aperture = 1ft^2 per 150 ft^2 of crawlspace floor area. U-factor: from Table 3.2(2) for floors over unconditioned spaces	Same as the Qualifying Home, but not less net free ventilation area than the Reference Home unless an approved ground cover in accordance with IRC 408.1 is used, in which case, the same net free ventilation area as the Qualifying Home down to a minimum net free vent area of 1ft^2 per 1,500 ft^2 of crawlspace floor area. Same as Qualifying Home
Ceilings:	Type: wood frame Gross area: same as Qualifying Home U-Factor: from Table 3.2(2)	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home

Table 3.2(1) Specifications for the Reference and Qualifying Homes

Building Component	**Reference Home**	**Qualifying Home**
Roofs:	Type: composition shingle on wood sheathing Gross area: same as Qualifying Home Solar absorptance = 0.75 Emittance = 0.90	Same as Qualifying Home Same as Qualifying Home Values from Table 3.3 shall be used to determine solar absorptance except where test data is provided for roof surface in accordance with ASTM Standards C-1549, E-1918, or CRRC Method # 1. Emittance values provided by the roofing manufacturer in accordance with ASTM Standard C-1371 shall be used when available. In cases where the appropriate data are not known, same as Qualifying Home
Attics:	Type: vented with aperture = 1ft^2 per 300 ft^2 ceiling area	Same as Qualifying Home
Foundations:	Type: same as Qualifying Home Gross Area: same as Qualifying Home U-Factor / R-value: from Table 3.2(2)	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home
Doors:	Area: 40 ft^2 Orientation: North U-factor: same as fenestration from Table 3.2(2)	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home
Glazing: [(a)]	Total area[(b)] = (a) The Qualifying Home glazing area; where the Qualifying Home glazing area is less than 18% of the conditioned floor area (b) 18% of the conditioned floor area; where the Qualifying Home glazing area is 18% or more of the conditioned floor area Orientation: equally distributed to four (4) cardinal compass orientations (N,E,S,&W)	Same as Qualifying Home Same as Qualifying Home Same as Qualifying Home

Table 3.2(1) Specifications for the Reference and Qualifying Homes

Building Component	Reference Home	Qualifying Home
	U-factor: from Table 3.2(2) SHGC: from Table 3.2(2) Interior shade coefficient: Summer = 0.70 Winter = 0.85 External shading: none	Same as Qualifying Home Same as Reference Home [(c)] Same as Qualifying Home
Skylights	None	Same as Qualifying Home
Thermally isolated sunrooms	None	Same as Qualifying Home
Air exchange rate	Specific Leakage Area (SLA) [(d)] = 0.00036 assuming no energy recovery	For residences that are not tested, the same as the Reference Home For residences without mechanical ventilation systems that are tested in accordance with Section802 of the RESNET Standards (2013),[6] the measured air exchange rate [(e)] but not less than 0.35 ach. For residences with mechanical ventilation systems that are tested in accordance with Chapter 802 of the RESNET Standards (2013),[5] the measured air exchange rate [(e)] combined with the mechanical ventilation rate,[(f)] which shall not be less than 0.01 x CFA + 7.5 x (Nbr+1) cfm.
Mechanical ventilation:	None, except where a mechanical ventilation system is specified by the Qualifying Home, in which case: Annual vent fan energy use: kWh/yr = 0.03942*CFA + 29.565*(N_{br}+1) (per dwelling unit) where:	Same as Qualifying Home Same as Qualifying Home

[5] RESNET, January 2013, *Mortgage Industry National Home Energy Rating System Standards*. Residential Energy Services Network, Oceanside, CA.

Table 3.2(1) Specifications for the Reference and Qualifying Homes

Building Component	**Reference Home**	**Qualifying Home**
	CFA = conditioned floor area N_{br} = number of bedrooms	
Internal gains:	As specified by Table 3.2(4)	Same as Reference Home, except as provided by Section 303.4.1.7.2, RESNET Standards (2013).[6]
Internal mass:	An internal mass for furniture and contents of 8 pounds per square foot of floor area	Same as Reference Home, plus any additional mass specifically designed as a Thermal Storage Element [(g)] but not integral to the building envelope or structure
Structural mass:	For masonry floor slabs, 80% of floor area covered by R-2 carpet and pad, and 20% of floor directly exposed to room air	Same as Qualifying Home
	For masonry basement walls, same as Qualifying Home, but with insulation required by Table 3.2(2) located on the interior side of the walls	Same as Qualifying Home
	For other walls, for ceilings, floors, and interior walls, wood frame construction	Same as Qualifying Home
Heating systems [(h),(i)]	Fuel type: same as Qualifying Home	Same as Qualifying Home [(i)]
	Efficiencies:	
	Electric: air source heat pump with efficiency in accordance with Table 3.2(1)(a)	Same as Qualifying Home
	Non-electric furnaces: natural gas furnace with efficiency in accordance with Table 3.2(1)(a)	Same as Qualifying Home
	Non-electric boilers: natural gas boiler with efficiency in accordance with Table 3.2(1)(a)	Same as Qualifying Home
	Capacity: sized in accordance with Section 303.5.1.4, RESNET Standards (2013).[6]	Same as Qualifying Home
Cooling systems [(h),(k)]	Fuel type: Electric	Same as Qualifying Home [(k)]

Table 3.2(1) Specifications for the Reference and Qualifying Homes

Building Component	**Reference Home**	**Qualifying Home**
	Efficiency: in accordance with Table 3.2(1)(a) Capacity: sized in accordance with Section 303.5.1.4, RESNET Standards (2013).[6]	Same as Qualifying Home Same as Qualifying Home
Thermal distribution systems:	A thermal distribution system efficiency (DSE) of 0.80 shall be applied to both the heating and cooling system efficiencies.	As specified by Table 3.2(3), except when tested in accordance with ASHRAE Standard 152-2004[(m)], and then either calculated through hourly simulation or calculated in accordance with ASHRAE Standard 152-2004
Thermostat	Type: manual Temperature setpoints: cooling temperature set point = 78 F; heating temperature set point = 68 F	Type: Same as Qualifying Home Temperature setpoints: same as the Reference Home, except as provided by Section 303.5.1.1, RESNET Standards (2013).[6]

Table 3.2(1) Notes:

(a) Glazing shall be defined as sunlight-transmitting fenestration, including the area of sash, curbing or other framing elements, that enclose conditioned space. Glazing includes the area of sunlight-transmitting fenestration assemblies in walls bounding conditioned basements. For doors where the sunlight-transmitting opening is less than 50% of the door area, the glazing area is the sunlight transmitting opening area shall be used. For all other doors, the glazing area is the rough frame opening area for the door, including the door and the frame.

(b) For homes with conditioned basements and for multi-family attached homes the Reference Home glazing area shall be the smaller of the Qualifying Home glazing area or the Standard glazing area (A_S) calculated using the following equation:

$A_S = 0.18 \times CFA \times F_A \times F$

where:

A_S = Standard glazing area

CFA = Conditioned Floor Area

F_A = (Above-grade thermal boundary gross wall area) / (above-grade gross thermal boundary wall area + 0.5 x below-grade gross thermal boundary wall area)

F = (Above-grade gross thermal boundary wall area) / (above-grade gross thermal boundary wall area + common wall area) or 0.56, whichever is greater

and where:

Thermal boundary wall is any wall that separates conditioned space from unconditioned space or ambient conditions, including the area of band joists or other inter-floor structure.

Above-grade thermal boundary wall is any portion of a thermal boundary wall not in contact with soil

Below-grade thermal boundary wall is any portion of a thermal boundary wall in soil contact

Common wall is the total wall area of walls adjacent to another conditioned living unit, not including foundation walls.

(c) For fenestrations facing within 15 degrees of due south that are directly coupled to thermal storage mass, the winter interior shade coefficient shall be permitted to increase to 0.95 in the Qualifying Home.

(d) Where Leakage Area (L) is defined in accordance with Section 5.1 of ASHRAE Standard 119 and where SLA = L / CFA (where L and CFA are in the same units). Either hourly calculations using the procedures given in the 2001 *ASHRAE Handbook of Fundamentals*, Chapter 26, page 26.21, equation 40 (Sherman-Grimsrud model) or calculations yielding equivalent results shall be used to determine the energy loads resulting from air exchange.

(e) Tested envelope leakage shall be determined and documented by a Certified Rater using the on-site inspection protocol as specified in Appendix A under "Blower Door Test." Either hourly calculations using the procedures given in the 2001 *ASHRAE Handbook of Fundamentals*, Chapter 26, page 26.21, equation 40 (Sherman-Grimsrud model) or calculations yielding equivalent results shall be used to determine the energy loads resulting from air exchange.

(f) The combined air exchange rate for infiltration and mechanical ventilation shall be determined in accordance with equation 43 of 2001 *ASHRAE Handbook of Fundamentals* page 26.24 in combination with the" Whole-house Ventilation" provisions of 2001 *ASHRAE Handbook of Fundamentals*, page 26.19 for intermittent mechanical ventilation.

(g) Thermal storage element shall mean a component not normally part of the floors, walls, or ceilings that is part of a passive solar system, and that provides thermal storage such as enclosed water columns, rock beds, or phase change containers. A thermal storage element must be in the same room as fenestration that faces within 15 degrees of due south, or must be connected to such a room with pipes or ducts that allow the element to be actively charged.

(h) For a Qualifying Home with multiple heating, cooling, or water heating systems using different fuel types, the applicable system capacities and fuel types shall be weighted in accordance with the loads distribution (as calculated by accepted engineering practice for that equipment and fuel type) of the subject multiple systems. For the Reference Home, the efficiencies given in Table 3.2(1)(a) below will be assumed when:

1) A type of device not covered by NAECA is found in the Qualifying Home;
2) The Qualifying Home is heated by electricity using a device other than an air source heat pump; or
3) The Qualifying Home does not contain one or more of the required HVAC equipment systems.

Table 3.2(1)(a). Standard Reference Home Heating and Cooling Equipment Efficiencies (i) (k) (m) (n)

Qualifying Home Fuel	Function	Reference Home Device
Electric	Heating	7.7 HSPF air source heat pump
Non-electric warm air furnace or space heater	Heating	78% AFUE gas furnace
Non-electric boiler	Heating	80% AFUE gas boiler
Any type	Cooling	13 SEER electric air conditioner

(i) For a Qualifying Home without a proposed heating system, a heating system with the efficiency specified in Table 3.2(1)(a) shall be assumed for both the Reference Home and Qualifying Home. For electric heating systems, an air-source heat pump with efficiency in accordance with Table 3.2(1)(a) shall be selected.
(k) For a Qualifying Home without a proposed cooling system, an electric air conditioner with efficiency specified in Table 3.2(1)(a) shall be assumed for both the Reference Home and the Qualifying Home.
(m) Tested duct leakage shall be determined and documented by a Certified Rater using the on-site inspection protocol specified by the *Mortgage Industry National Home Energy Rating Standards*, Appendix A under "Air leakage (ducts)".

Table 3.2(2). Component Heat Transfer Characteristics for Reference Home [(a)]

Climate Zone [(b)]	Fenestration and Opaque Door U-Factor	Glazed Fenestration Assembly SHGC	Ceiling U-Factor	Frame Wall U-Factor	Floor Over Unconditioned Space U-Factor	Basement Wall U-Factor [(c)]	Slab-on-Grade [(d, e)] R-Value & Depth
1	1.20	0.40	0.035	0.082	0.064	0.360	0
2	0.75	0.40	0.035	0.082	0.064	0.360	0
3	0.65	0.40	0.035	0.082	0.047	0.360	0
4 except Marine	0.40	0.40	0.030	0.082	0.047	0.059	10, 2 ft.
5 and Marine 4	0.35	0.40	0.030	0.060	0.033	0.059	10, 2 ft.
6	0.35	0.40	0.026	0.060	0.033	0.059	10, 4 ft.
7 and 8	0.35	0.40	0.026	0.057	0.033	0.059	10, 4 ft.

Table 3.2(2) Notes:

(a) Non-fenestration U-Factors shall be obtained from measurement, calculation, or an approved source.

(b) Climates zones shall be as specified by the 2004 Supplement to the International Energy Conservation Code.

(c) For basements where the conditioned space boundary comprises the basement walls.

(d) R-5 shall be added to the required R-value for slabs with embedded heating.

(e) Insulation shall extend downward from the top of the slab vertically to the depth indicated.

Table 3.2(3) Default Distribution System Efficiencies for Inspected Systems [(a)]

Distribution System Configuration and Condition:	**Forced Air Systems**	**Hydronic Systems** [(b)]
Distribution system components located in unconditioned space	0.80	0.95
Distribution systems entirely located in conditioned space [(c)]	0.88	1.00
Proposed "reduced leakage" with entire air distribution system located in the conditioned space [(d)]	0.96	
Proposed "reduced leakage" air distribution system with components located in the unconditioned space	0.88	
"Ductless" systems [(e)]	1.00	

Table 3.2(3) Notes:

(a) Default values given by this table are for distribution systems as rated, which meet minimum IECC 2000 requirements for duct system insulation.

(b) Hydronic Systems shall mean those systems that distribute heating and cooling energy directly to individual spaces using liquids pumped through closed loop piping and that do not depend on ducted, forced air flows to maintain space temperatures.
(c) Entire system in conditioned space shall mean that no component of the distribution system, including the air handler unit or boiler, is located outside of the conditioned space boundary.
(d) Proposed “reduced leakage” shall mean leakage not greater than 3 cfm to outdoors per 100 square feet of conditioned floor area and not greater than 9 cfm total air leakage per 100 square feet of conditioned floor area at a pressure differential of 25 Pascal across the entire system, including the manufacturer’s air handler enclosure. Total air leakage of not greater than 3 cfm per 100 square feet of conditioned floor area at a pressure difference of 25 Pascal across the entire system, including the manufacturer’s air handler enclosure, shall be deemed to meet this requirement without measurement of air leakage to outdoors. This rated condition shall be specified as the required performance in the construction documents and requires confirmation through field-testing of installed systems as documented by a Certified Rater.
(e) Ductless systems may have forced airflow across a coil but shall not have any ducted airflows external to the manufacturer’s air handler enclosure.

Table 3.2(4). Internal Gains for Reference Home [(a)]

End Use / Component	**Sensible Gains (Btu/day)**			**Latent Gains (Btu/day)**		
	a	**b**	**c**	**a**	**b**	**c**
Residual MELs		7.27			0.38	
Interior lighting	4,253	7.48				
Refrigerator	5,955		168			
TVs	3,861		645			
Range/Oven (elec) [(b)]	2,228		262	248		29
Range/Oven (gas) [(b)]	4,086		488	1,037		124
Clothes Dryer (elec) [(b)]	661		188	73		21
Clothes Dryer (gas) [(b)]	738		209	91		26
Dish Washer	219		87	219		87
Clothes Washer	95		26	11		3
Gen water use	-1227		-409	1,245		415
Occupants [(c)]			3716			2,884

Notes for Table 3.2(4)

(a) Table values are coefficients for the following general equation:
Gains = a + b*CFA + c*Nbr
where CFA = Conditioned Floor Area and Nbr = Number of bedrooms.
(b) For Rated Homes with electric appliance use (elec) values and for Rated homes with natural gas-fired appliance use (gas) values
(c) Software tools shall use either the occupant gains provided above or similar temperature dependent values generated by the software where number of occupants equals the number of bedrooms and occupants are present in the home for 16.5 hours per day.

Table 3.3 Default Solar Absorptance for Various Roofing Surfaces[6]

Roof Materials	Absorptance	Roof Materials	Absorptance
Composition Shingles		Wood Shingles	
Dark	0.92	Dark	0.90
Medium	0.85	Medium	0.80
Light	0.75		
		Concrete/Cement	
Tile/Slate		Dark	0.90
Dark	0.90	Medium	0.75
Medium	0.75	Light	0.60
Terra cotta	0.65	White	0.30
Light	0.60		
White	0.30	Membrane	
		Dark	0.90
Metal		Medium	0.75
Dark	0.90	Light	0.60
Medium	0.75	White	0.30
Galvanized, unfinished	0.70		
Light	0.60	Built-Up (gravel surface)	
Galvalum, unfinished	0.35	Dark	0.92
White	0.30	Medium	0.85
		Light	0.75

[6] Source: Parker, D S, J E R McIlvaine, S F Barkaszi, D J Beal and M T Anello (2000). Laboratory Testing of the Reflectance Properties of Roofing Material. FSEC-CR670-00. Florida Solar Energy Center, Cocoa, FL. Available online at: http://www.fsec.ucf.edu/bldg/pubs/cr670/

Appendix B

Acceptance Criteria for Building Loads Tests

ANSI/ASHRAE Standard 140, Class II, Tier 1 Tests. The ANSI/ASHRAE Standard 140-2011, Class II, Tier 1 test procedure is a requirement for all software programs to be accredited. The acceptance criteria for this test suite are developed in accordance with Annex 22 of ANSI/ASHRAE Standard 140-2011and are as follows:

Annual Heating Loads:
Colorado Springs, CO

Heating	range max	range min
L100AC	79.48	48.75
L110AC	103.99	71.88
L120AC	64.30	37.82
L130AC	53.98	41.82
L140AC	56.48	43.24
L150AC	71.33	40.95
L155AC	74.18	43.53
L160AC	81.00	48.78
L170AC	92.40	61.03
L200AC	185.87	106.41
L202AC	190.05	111.32
L302XC	90.52	52.66
L304XC	75.32	43.91
L322XC	118.20	68.35
L324XC	80.04	44.01

Annual Heating Load deltas:
Colorado Springs, CO

Heating	range max	range min
L110AC-L100AC	28.12	19.37
L120AC-L100AC	-7.67	-18.57
L130AC-L100AC	-5.97	-27.50
L140AC-L100AC	-4.56	-24.42
L150AC-L100AC	-3.02	-12.53
L155AC-L150AC	6.88	-1.54
L160AC-L100AC	5.10	-3.72
L170AC-L100AC	17.64	7.12
L200AC-L100AC	107.66	56.39
L202AC-L200AC	9.94	-0.51
L302XC-L100AC	14.50	-3.30
L302XC-L304XC	17.75	5.66
L322XC-L100AC	39.29	15.71
L322XC-L324XC	38.27	20.21

Annual Cooling Loads:
Las Vegas, NV

Cooling	range max	range min
L100AL	64.88	50.66
L110AL	68.50	53.70
L120AL	60.14	47.34
L130AL	45.26	32.95
L140AL	30.54	19.52
L150AL	82.33	62.41
L155AL	63.06	50.08
L160AL	72.99	58.61
L170AL	53.31	41.83
L200AL	83.43	60.25
L202AL	75.96	52.32

Annual Cooling Load deltas:
Las Vegas, NV

Cooling	range max	range min
L110AL-L100AL	7.84	-0.98
L120AL-L100AL	0.68	-8.67
L130AL-L100AL	-13.71	-24.40
L140AL-L100AL	-27.14	-38.68
L150AL-L100AL	20.55	8.72
L155AL-L150AL	-9.64	-22.29
L160AL-L100AL	12.28	3.88
L170AL-L100AL	-4.83	-15.74
L200AL-L100AL	21.39	6.63
L200AL-L202AL	14.86	2.03

Appendix C

Reference Home Auto-Generation Test Suite for Verification of Software Tools Used for Tax Incentive Qualification

Introduction

This report contains recommendations regarding the reference home auto-generation test suite for tax credit qualification. The Reference Home auto-generation test suite is one of four minimum test suites that this Standard requires for software tools used for tax incentive qualification. The test cases in this proposed test suite are designed to verify that software tools automatically generate accurate Reference Homes given only the building information for the Qualifying home.

Reporting

Software tools applying for verification shall provide evidence that their software meets the requirements of this test suite. The software tool provider or software vendor is responsible for producing the documentation needed to show that the software has been verified through this test suite. In some cases, the data needed to verify accuracy is of no interest or value to the end-user of the software, but in any case, the software tool must generate it.

Minimum Requirements

At a minimum, software tools applying for accreditation must report the following values for the Reference Home:

1. Areas and overall U-factors (or R-values in the case of slab-on-grade construction) for all building components, including ceilings, walls, floors, windows (by orientation) and doors.
2. Overall solar-heat gain coefficient ($SHGC_o$)[7] of the windows during heating.
3. Overall solar-heat gain coefficient ($SHGC_o$) of the windows during cooling.
4. Wall solar absorptance and infrared emittance
5. Roof solar absorptance and infrared emittance
6. Total internal gains to the home (Btu/day)
7. Specific leakage area (SLA) for the building, by zone or as SLA_o[8], as appropriate

[7] The overall solar heat gain coefficient ($SHGC_o$) of a fenestration is defined as the solar heat gain coefficient (SHGC) of the fenestration product taken in combination with the interior shade fraction for the fenestration.

[8] SLA_o is the floor-area weighted specific leakage area of a home where the different building zones (e.g. basement and living zones) have different specific leakage areas.

8. Attic net free ventilation area (ft^2)
9. Crawlspace net free ventilation area (ft^2), if appropriate
10. Exposed masonry floor area and carpet and pad R-value, if appropriate
11. Heating system labeled ratings, including AFUE, COP, or HSPF, as appropriate.
12. Cooling system labeled ratings, including SEER or EER, as appropriate.
13. Thermostat schedule for heating and cooling
14. Air Distribution System Efficiency (DSE).
15. Mechanical ventilation kWh/yr, if appropriate

Software tools must have the ability to recreate or store the test case Reference Homes as if they were Qualifying Homes such that they also can be simulated and evaluated as Qualifying Homes.

Auto-generation Test Suite

Test Case1. HERS BESTEST case L100 building configured as specified in the HERS BESTEST procedures, located in Baltimore, MD, including a total of 3 bedrooms and the following mechanical equipment: gas furnace with AFUE = 82% and central air conditioning with SEER = 11.0; a gas range, oven and clothes dryer; all other appliances are electric.

Test Case 2. HERS BESTEST case L100 configured on an un-vented crawlspace with R-7 crawlspace wall insulation, located in Dallas, TX, including a total of 3 bedrooms and the following mechanical equipment: electric heat pump with HSPF = 7.5 and SEER = 12.0; all appliances are electric.

Test Case 3. HERS BESTEST case L304 in Miami, configured as specified in the HERS BESTEST procedures, located in Miami, FL, including a total of 2 bedrooms and the following mechanical equipment: electric strip heating with COP = 1.0 and central air conditioner with SEER = 15.0; all appliances are electric.

Test Case 4. HERS BESTEST case L324 configured as specified as in the HERS BESTEST procedures, located in Colorado Springs, CO, including a total of 4 bedrooms and the following mechanical equipment: gas furnace with AFUE = 95% and no air conditioning; a gas range, oven and clothes dryer; all other appliances are electric.

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

Verification Criteria

Test Cases 1 – 4. For test cases 1 through 4 the values contained in Table 1 shall be used as the verification criteria for software tool accreditation. For Reference Home building components marked by an asterisk (*), the verification criteria may include a range equal to ± 0.05% of the listed value. For all other Reference Home components the listed value is exact.

Table 1. Verification Criteria for Test Cases 1 – 4

Reference Home Building Component	Test 1	Test 2	Test 3	Test 4
Above-grade walls (U_o)	0.082	0.082	0.082	0.060
Above-grade wall solar absorptance (α)	0.75	0.75	0.75	0.75
Above-grade wall infrared emittance (ε)	0.90	0.90	0.90	0.90
Basement walls (U_o)	n/a	n/a	n/a	0.059
Above-grade floors (U_o)	0.047	0.047	n/a	n/a
Slab insulation R-Value	n/a	n/a	0	0
Ceilings (U_o)	0.030	0.035	0.035	0.030
Roof solar absorptance (α)	0.75	0.75	0.75	0.75
Roof infrared emittance (ε)	0.90	0.90	0.90	0.90
Attic vent area* (ft^2)	5.13	5.13	5.13	5.13
Crawlspace vent area* (ft^2)	n/a	10.26	n/a	n/a
Exposed masonry floor area * (ft^2)	n/a	n/a	307.8	307.8
Carpet & pad R-Value	n/a	n/a	2.0	2.0
Door Area (ft^2)	40	40	40	40
Door U-Factor	0.40	0.65	1.20	0.35
North window area* (ft^2)	67.50	67.50	67.50	67.50
South window area* (ft^2)	67.50	67.50	67.50	67.50
East window area* (ft^2)	67.50	67.50	67.50	67.50
West window area* (ft^2)	67.50	67.50	67.50	67.50
Window U-Factor	0.40	0.65	1.20	0.35
Window $SHGC_o$ (heating)	0.34	0.34	0.34	0.34
Window $SHGC_o$ (cooling)	0.28	0.28	0.28	0.28
SLA_o* (ft^2/ft^2)	0.00036	0.00036	0.00036	0.00036
Sensible Internal gains* (Btu/day)	55,470	52,794	48,111	83,103
Latent Internal gains* (Btu/day)	13,807	12,698	9,259	17,934
Labeled heating system rating and efficiency	AFUE = 78%	HSPF = 7.7	HSPF = 7.7	AFUE = 78%
Labeled cooling system rating and efficiency	SEER = 13.0	SEER = 13.0	SEER = 13.0	SEER = 13.0
Air Distribution System Efficiency	0.80	0.80	0.80	0.80
Thermostat Type	Manual	Manual	Manual	Manual
Heating thermostat settings	68 F (all hours)	68 F (all hours)	68 F (all hours)	68 F (all hours)
Cooling thermostat settings	78 F (all hours)	78 F (all hours)	78 F (all hours)	78 F (all hours)

Test Case 5. Test case 5 requires that each of the Reference Homes for test cases 1-4 be stored or recreated in the software tool as a Qualifying Home and simulated as any other qualifying home would be simulated. If the resulting Qualifying home is correctly configured to be identical to its appropriate Reference Home, energy use calculations arising from normal operation of the software tool should produce virtually identical energy use for both the Reference Home and the Qualifying Home for this round of tests.

For test case 5, the energy use e-Ratio shall be calculated separately from the simulation results for heating and cooling, as follows:

e-Ratio = (Qualifying Home energy use) / (Reference Home Energy Use)

Verification criteria for these calculations shall be ± 0.5% of 1.00. Thus, for each of the preceding test cases (1-4), the e-Ratio resulting from these software tool simulations and the subsequent e-Ratio calculations shall be greater than or equal to 0.995 **and** less than or equal to 1.005.

Appendix D

RESNET HVAC Test Suites 1 & 2

Required Capabilities

Tools must be capable of generating HVAC results using system type and efficiency as inputs. Additional efficiency information is allowable, but must not be required to operate the tool. Tools must also account for duct leakage, duct insulation levels and the presence of a programmable thermostat.

System Types

System types that must be supported by all tools:

1. Compressor based air conditioning system
2. Oil, propane or natural gas forced air furnaces
3. Electric resistance forced air furnaces
4. Air source heat pump

Optional system types that may be supported include:

1. Evaporative cooling, direct, indirect or IDEC
2. Ground or water source heat pumps
3. Multiple fossil fuel systems which utilize fuel for backup heating and an electric air or ground source heat pump for primary heating. An example of this would be an electric air source heat pump with a fossil fuel furnace as a supplement or backup.
4. Radiant heating systems including but not limited to hot water radiant floor systems, baseboard systems and ceiling cable systems.
5. Hydronic systems.
6. Combo systems in which the system supplies both domestic hot water and space heating.
7. Active solar space heating systems

Capability tests do not currently exist for the optional system types listed above. The following table lists the efficiency metrics that are reported by manufacturers and must be used for each system type.

HVAC Equipment Type	**Heating Efficiency Metric**	**Cooling Efficiency Metric**	**Comments:**
Gas or Fuel Furnaces	AFUE		Includes wall furnaces, floor furnaces and central forced air furnaces.
Electric Resistance Furnace	COP		Use COP of 1.0, an HSPF of 3.413 may be equivalent and acceptable for some tools.
Air Source Heat Pump <65 kBtu/h	HSPF	SEER	
Air Cooled Central Air Conditioner <65 kBtu/h		SEER	
Air Cooled Window Air Conditioner		**EER**	PTAC units are included in this category

Detailed Default Inputs

Where tools use detailed modeling capabilities for HVAC simulation like DOE-2, the following values should be used as default values in the simulation tool to achieve the best results.

Default Values for use with Detailed HVAC Simulation Tools

DOE-2 Keyword:	**Description (units)**	**Value**
HEATING-EIR	Heat Pump Energy Input Ratio compressor only, (1/cop)	0.582*(1/(HSPF/3.413))
COOLING-EIR	Air Conditioner Energy Input Ratio compressor only, (1/cop)	0.941*(1/(SEER/3.413))
DEFROST-TYPE	Defrost method for outdoor unit, (Reverse cycle)	REVERSE-CYCLE
DEFROST-CTRL	Defrost control method, (Timed)	TIMED
DEFROST-T (F)	Temperature below which defrost controls are activated, (^{o}F)	40^{o}
CRANKCASE-HEAT	Refrigerant crankcase heater power, (kW)	0.05
CRANK-MAX-T	Temperature above which crankcase heat is deactivated, (^{o}F)	50^{o}
MIN-HP-T (F)	Minimum temperature at which compressor operates,	0^{o}

DOE-2 Keyword:	Description (units)	Value
	(^{o}F)	
MAX-HP-SUPP-T	Temperature above which auxiliary strip heat is not available, (^{o}F)	50^o
MAX-SUPPLY-T (heating, heat pump)	Maximum heat pump leaving air temperature from heating coil, (^{o}F)	105^o
MAX-SUPPLY-T (heating, natural gas furnace)	Maximum gas furnace leaving air temperature from heating coil, (^{o}F)	120^o
FURNACE-AUX	Natural gas furnace pilot light energy consumption, (Btu/h)	100
MIN-SUPPLY-T (cooling)	Minimum cooling leaving air temperature from cooling coil, (^{o}F)	55^o
SUPPLY-KW	Indoor unit standard blower fan power, (kW/cfm)	0.0005
SUPPLY-DELTA-T	Air temperature rise due to fan heat, standard fan, (^{o}F)	1.580
SUPPLY-KW	Indoor unit standard blower fan power, high efficiency fan, (kW/cfm)	0.000375
SUPPLY-DELTA-T	Air temperature rise associated due to fan heat, high efficiency fan, (^{o}F)	1.185
COIL-BF	Coil bypass factor, (dimensionless)	0.241
Other parameters:		
Part load performance curves	Compressor part load performance curves	Henderson, et.al.[9]
Heating system size	Installed heat pump size, (kBtu/h)	Determined by Manual J (specified)
Coil airflow	Indoor unit air flow, (cfm)	30 cfm/(kBtu/h)
Cooling system size	Installed air conditioner size, (kBtu/h)	Determined by Manual J (specified)

[9] Henderson, H.I., D.S. Parker and Y.J. Huang, 2000. "Improving DOE-2's RESYS Routine: User Defined Functions to Provide More Accurate Part Load Energy Use and Humidity Predictions," Proceedings of 2000 Summer Study on Energy Efficiency in Buildings, Vol. 1, p. 113, American Council for an Energy-Efficient Economy, 1001 Connecticut Avenue, Washington, DC.

List of Tests

The following test suites represent tests that tools must pass to be accredited. All tests are to be performed using the L100 building case described by the HERS BESTEST procedures.[10]

For each test case, interim acceptance criteria are provided. These interim criteria are based on preliminary reference results from 5 tools, which are capable of detailed hourly building simulation and HVAC modeling computations (e.g. DOE-2). The criteria are established for interim purposes as the 90% confidence interval for the 5 preliminary sets of reference results. In order to pass a specific test, tools must predict percentage energy use changes for the specified heating and/or cooling system tests that falls between the upper and lower acceptance criteria for that test.

Tools that do not model the performance of HVAC equipment in detail must provide for climate adjusted equipment performance factors in order to fall within the acceptance criteria for these tests. Methods of adjusting the manufacturer's nameplate ratings to account for climate dependent performance have been reported.[11]

Test Suite 1 – Air conditioning systems: Test to ensure that there is the proper differential electrical cooling energy consumption by cooling systems when the efficiency is varied between SEER 10 and a higher efficiency unit, taken to be SEER 13. For the purposes of this test assume zero duct leakage and all ducts and air handlers are in conditioned space.

Air Conditioning System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC1a	Air cooled air conditioner	38.3 kBtu/h	Las Vegas, NV	SEER = 10
HVAC1b	Air cooled air conditioner	38.3 kBtu/h	Las Vegas, NV	SEER = 13

Interim Air Conditioning System Acceptance Criteria

Test #	Mfg. Equip Performance Rating (MEPR) Change	Low Acceptance Criteria	High Acceptance Criteria
HVAC1a	Base case	---	---
HVAC1b	-23.1%	-20.0%	-18.4%

[10] 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. (Also available online at http://www.nrel.gov/publications/.)
[11] Fairey, P., D.S. Parker, B. Wilcox and M. Lombardi, "Climate Impacts on Heating Seasonal Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) for Air Source Heat Pumps." ASHRAE Transactions, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA, June 2004. (Also available online at http://www.fsec.ucf.edu/bldg/pubs/hspf/)

<u>Test Suite 2 – Heating Systems:</u> Test to ensure that there is differential heating energy consumed by heating systems when the efficiency is varied between a code minimum heating and a higher efficiency unit. The tests will be carried out for both electric and non-electric heating systems. For the purposes of this test assume zero duct leakage and all ducts and air handlers in conditioned space. .

Gas Heating System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC2a	Gas Furnace	56.1 kBtu/h	Colorado Springs, CO	AFUE = 78%
HVAC2b	Gas Furnace	56.1 kBtu/h	Colorado Springs, CO	AFUE = 90%

Interim Gas Heating System Acceptance Criteria

Test #	Mfg. Equip Performance Rating (MEPR) Change	Low Acceptance Criteria	High Acceptance Criteria
HVAC2a	Base case	---	---
HVAC2b	-13.3%	-13.1%	-12.6%

Electric Heating System Test Specifications

Test #	System Type	Capacity	Location	Efficiency
HVAC2c	Air Source Heat Pump	56.1 kBtu/h	Colorado Springs, CO	HSPF = 6.8
HVAC2d	Air Source Heat Pump	56.1 kBtu/h	Colorado Springs, CO	HSPF = 9.85
HVAC2e	Electric Furnace	56.1 kBtu/h	Colorado Springs, CO	COP =1.0

Interim Electric Heating System Acceptance Criteria

Test #	Mfg. Equip Performance Rating (MEPR) Change	Low Acceptance Criteria	High Acceptance Criteria
HVAC2c	Base case	---	---
HVAC2d	-31.0%	-26.0%	-19.1%
HVAC2e	99.2%	47.8%	63.4%

Appendix E

RESNET Distribution System Efficiency (DSE) Test Suite

Distribution System Efficiency (DSE) tests are designed to ensure that the impact of duct insulation, duct air leakage and duct location are properly accounted for in software. Tables 1 and 2 below describe the test specifications and the bounds criteria for these important tests.

Test Case Specification

For all tests, assume that the air-handling unit is in conditioned space. If the software tool being tested has the ability to modify inputs for duct area, assume that the supply duct area is equal to 20% of the conditioned floor area and the return duct area is equal to 5% of the conditioned floor area. The duct leakage shall be 250 cfm_{25} for cases 3d and 3h with the return and supply leakage fractions each set at 50%. All tests assume a natural gas forced air furnace and forced air cooling system with efficiencies of 78% AFUE = 78% for the heating system and SEER = 10 for the cooling system.

Furnace and air conditioner heating and cooling capacities should be modified for each of the duct system efficiency test cases according to the values provided in Tables 1a and 2a. Similarly, the specified heating and cooling coil airflow (cfm) should be altered by case using a value of 360 cfm/ton (30 cfm/kBtu) of capacity. Also, the exterior air film resistance of the duct system should be added to the specified duct R-values given in Tables 1a and 2a to obtain agreement for duct conductance. For non-insulated sheet metal ducts (R-0) the air film has a resistance of approximately R=1.5 ft^2-^oF-hr/Btu and for insulated ducts (R=6) the air film has a resistance of R=1.0 as shown by test results obtained by Lauvray (1978) at a typical residential duct airflow rate of 530 fpm.[12] These values are currently established for the purposes of duct design calculations by ASHRAE within the Handbook of Fundamentals (2001, p. 34.15). Thus, unless the software undergoing test accounts for these film resistances, the uninsulated sheet metal duct (R=0 in Tables 1a and 2a) should be entered as R=1.5 while the insulated ducts (R=6 in tables) should be entered as R=7.

For the heating comparison test cases (Table 1a), which assume a basement, use the HERS BESTEST Case L322 home. The basement is to be unconditioned, have a floor area equal to the main floor area (1539 ft^2) and have R11 insulation in the floor joists of the main floor with a framing fraction of 13%. The basement case has no basement wall insulation. For the cooling comparison test cases (Table 2a), use the HERS BESTEST case L100 home.

[12] T.L. Lauvray, 1978. "Experimental heat transmission coefficients for operating air duct systems," ASHRAE Journal, June, 1978.

Bounds Criteria

The bounds criteria for these tests were established using ASHRAE Standard 152-04, using the spreadsheet tool constructed for the U.S. DOE *Building America* program by Lawrence Berkeley National Laboratory (LBNL).[13] In all cases, the input values for the Standard 152 calculations assumed the following:

- Single story building
- Single speed air conditioner/heating system
- System capacities as specified in Tables 1a and 2a
- Coil air flow = 360 cfm per 12,000 Btu/h
- Ducts located as specified in Tables 1a and 2a
- Supply duct area = 308 ft^2
- Return duct area = 77 ft^2
- Supply and return duct insulation of R=1.5 and R=7 for uninsulated (R=0) and insulated (R=6) ducts, respectively
- Supply and return duct leakage = 125 cfm each, where so specified in Tables 1a and 2a.

Following the ASHRAE Standard 152 analysis, the resulting DSE values were converted to a percentage change in heating and cooling energy use ("Target Delta" in Tables 1b and 2b) using the following calculation:

$$\% \text{ Change} = 1.0 - (1.0 / \text{DSE})$$

Bounds criteria were then established as this target delta plus and minus 5% to yield the values given in Tables 1b and 2b for heating and cooling test minimum and maximum delta bounds criteria, respectively.

Heating Energy Tests

Table 1a. Heating Energy DSE Comparison Test Specifications

Test #	Location	System Type	System Capacity (kBtu/h)	Duct Location	Duct Leakage	Duct R-val*
HVAC3a (base case)	Colorado Springs, CO	Gas Furnace	46.6	100% conditioned	None	R=0
HVAC3b	Colorado Springs, CO	Gas Furnace	56.0	100% in basement	None	R=0
HVAC3c	Colorado Springs, CO	Gas Furnace	49.0	100% in basement	None	R=6
HVAC3d	Colorado Springs, CO	Gas Furnace	61.0	100% in basement	250 cfm_{25}	R=6

13 See http://www.eere.energy.gov/buildings/building_america/benchmark_def.html

* Duct R-value does not include air film resistances. For uninsulated ducts, this film resistance is approximately R=1.5 and for insulated ducts it is approximately R=1.0. If software does not consider this air film resistance in detail, then these air film resistances should be added.

Table 1b. Heating Energy DSE Comparison Test Bounds Criteria

Test #	Target Delta* Heating Energy Relative to HVAC3a	Minimum Delta* Heating Energy	Maximum Delta* Heating Energy
HVAC3a	Base case	---	---
HVAC3b	26.4%	21.4%	31.4%
HVAC3c	7.5%	2.5%	12.5%
HVAC3d	20%	15%	25%
* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100			

Cooling Energy Tests

Table 2a. Cooling Energy DSE Comparison Test Specifications

Test #	Location	System Type	System Capacity (kBtu/h)	Duct Location	Duct Leakage	Duct R-val*
HVAC3e (base case)	Las Vegas, NV	Air Conditioner	-38.4	100% conditioned	None	R=0
HVAC3f	Las Vegas, NV	Air Conditioner	-49.9	100% in attic	None	R=0
HVAC3g	Las Vegas, NV	Air Conditioner	-42.2	100% in attic	None	R=6
HVAC3h	Las Vegas, NV	Air Conditioner	-55.0	100% in attic	250 cfm_{25}	R=6
* Duct R-value does not include air film resistance. For uninsulated ducts, this film resistance is approximately R=1.5 and for insulated ducts it is approximately R=1.0. If software does not consider this air film resistance in detail, then these air film resistances should be added.						

Table 2b. Cooling Energy DSE Comparison Test Bounds Criteria

Test #	Target Delta* Cooling Energy Relative to HVAC3e	Minimum Delta* Cooling Energy	Maximum Delta* Cooling Energy
HVAC3e	Base case	---	---
HVAC3f	31.2%	26.2%	36.2%
HVAC3g	11.5%	6.5%	16.5%
HVAC3h	26.1%	21.1%	31.1%
* Delta = % Change in energy use = ((alternative – base case) / (base case)) * 100			

Appendix F

RESNET Service Hot Water Test Suite

1 Hot Water System Performance Tests

Hot water system tests are designed to determine if software tools accurately account for both the hot water use rate (gallons per day) and the climate impacts (inlet water temperatures) of hot water systems. The tests are limited to standard gas-fired hot water systems and cannot be used to evaluate solar hot water systems, heat pump hot water systems, hot water systems that recover heat from air conditioner compressors (heat recovery or de-super heater systems), or other types of hot water systems. In addition, distribution losses associated with hot water distribution systems are not covered by this test.

2 Test Description

The following table provides summary specifications for the six required hot water tests. The tests are segregated into two sets of three tests – one set of cold climate tests (Duluth, MN) and one set of hot climate tests (Miami, FL).

Table 2-1. Summary Specifications for Standard Hot Water Tests

Test Number	System Type	Climate Location	System Efficiency	Number of Bedrooms
DHW-MN-56-2	40 gal, gas	Duluth, MN	EF = 0.56	2
DHW-MN-56-4	40 gal, gas	Duluth, MN	EF = 0.56	4
DHW-MN-62-2	40 gal, gas	Duluth, MN	EF = 0.62	2
DHW-FL-56-2	40 gal, gas	Miami, FL	EF = 0.56	2
DHW-FL-56-4	40 gal, gas	Miami, FL	EF = 0.56	4
DHW-FL-62-2	40 gal, gas	Miami, FL	EF = 0.62	2

Additional specifications used in the creation of the reference results that establish the hot water system test acceptance criteria are as follows:

2.1 Hot Water Draw Profile

The hot water draw profile is as specified by ASHRAE Standard 90.2, as given in Table 2-2 below:

Table 2-2. Hourly Hot Water Draw Fraction for Hot Water Tests

Hour of Day	Daily Fraction	Hour of Day	Daily Fraction	Hour of Day	Daily Fraction
1	0.0085	9	0.0650	17	0.0370
2	0.0085	10	0.0650	18	0.0630
3	0.0085	11	0.0650	19	0.0630
4	0.0085	12	0.0460	20	0.0630
5	0.0085	13	0.0460	21	0.0630
6	0.0100	14	0.0370	22	0.0510
7	0.0750	15	0.0370	23	0.0510
8	0.0750	16	0.0370	24	0.0085

2.2 Inlet Mains Temperature

The cold-water inlet mains temperatures to the hot water system are calculated in accordance with the following formula:[14]

$$T_{mains} = (T_{amb,avg} + \mathit{offset}) + \mathit{ratio} * (\Delta T_{amb,max} / 2) * \sin(0.986 * (\text{day\#} - 15 - \mathit{lag}) - 90)$$

where:

- T_{mains} = mains (supply) temperature to domestic hot water tank (ºF)
- $T_{amb,avg}$ = annual average ambient air temperature (ºF)
- $\Delta T_{amb,max}$ = maximum difference between monthly average ambient temperatures (e.g., $T_{amb,avg,july} - T_{amb,avg,january}$) (ºF)
- 0.986 = degrees/day (360/365)
- day# = Julian day of the year (1-365)
- *offset* = 6°F
- *ratio* = $0.4 + 0.01 (T_{amb,avg} - 44)$
- *lag* = $35 - 1.0 (T_{amb,avg} - 44)$

2.3 Additional TRNSYS Simulation Parameters

Additional inputs for TRNSYS reference result simulations are as follows:

- Rated Power: 40,000 Btu/hr
- Recovery efficiency: 0.78
- Tank UA for EF=0.56 system: 10.79 Btu/hr-F
- Tank UA for EF=0.62 system: 7.031 Btu/hr-F
- Tank set point temperature: 120 F
- Tank space temperature (“loss temp”): 75 F
- Tank stratification: 15 equal nodes
- Simulation time step: 1/16th hour

[14] NREL, “Building America Research Benchmark Definition.” National Renewable Energy Laboratory, Golden, CO, December 29, 2004. May be found online at: http://www.eere.energy.gov/buildings/building_america/pa_resources.html

3 Acceptance Criteria

In each of the two sets of three test cases, the first test listed (DHW-xx-56-2) is the base case and the other two cases are the alternative cases. There are two metrics used for acceptance criteria a difference metric (delta) and an absolute metric (MBtu). 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 MBtu). The acceptance criteria given in Table 3-1 below are determined from reference results from three different software tools – TRNSYS version15, DOE-2.1E (v.120) as used by EnergyGauge USA version 2.5, and RemRate version 12. Minimum and maximum acceptance criteria are determined as the 99% confidence interval for these reference results using the student t-test.

Table 3-1. Acceptance Criteria for Hot Water Systems Tests

Case	Mean	St Dev	99%CI	Minimum	Maximum
MN,0.56,4 (delta)	29.3%	0.58%	2.85%	26.5%	32.2%
MN,0.62,2 (delta)	-9.3%	0.51%	2.49%	-11.8%	-6.8%
FL,0.56,4 (delta)	24.1%	1.02%	5.01%	19.1%	29.1%
FL,0.62,2 (delta)	-13.6%	1.19%	5.87%	-19.5%	-7.7%
MN,0.56,2 (MBtu)	20.13	0.38	1.89	18.24	22.02
FL,0.56,2 (MBtu)	12.69	0.36	1.76	10.92	14.45
MN-FL (MBtu)	7.44	0.40	1.95	5.49	9.39

Appendix G

RESNET/HERS BESTEST L125A Test Case

1. Background

Test Case L125A is developed as an additional HERS BESTEST case to examine potential interactions between home alterations that interact with one another in a way that causes their combined impact on energy use to be different than the sum of their individual impacts on energy use. HERS BESTEST Case L120A examines the impact of adding additional ceiling and wall insulation to the L100A Case (baseline) and Case L130A examines the impact of adding high performance windows to the L100A Case. This Case, named L125A combines test Case L120A and Case L130A to examine the impact of adding both sets of improvements to the L100A Case.

1.1. Test Case L125A Specifications. [15]

Case L125A is **exactly the same as Case L100A**, except that

- An extra layer of R-38 batt insulation has been added to the ceiling, and exterior walls have 2x6 24" O.C. framing and R-18 batt insulation with R-7.2 polyisocyanurate exterior board insulation; and

- All single-pane windows are replaced with double-pane low-emissivity (low-e) windows with wood frames and insulated spacers.

1.2. Acceptance Criteria for Test Case L125A

Acceptance criteria for Test Case L125A are developed in the same manner as for all other HERS BESTEST cases (as detailed in Appendix H of the User's Manual referenced above) except that for this test the criteria are developed from six software tools that are currently used in the marketplace as follows:

- *EnergyGauge® USA* by Florida Solar Energy Center
- *EnergyInsights* by Appogee Interactive
- *OptiMiser* by Energy Logic
- *Rem/Rate* by Architectural Energy Corporation
- *EnergyMeasure ™ Home* by Conservation Services Group
- *TREAT* by PSD Consulting

[15] Users are advised to consult the following reference for details: Judkoff, R. and J. Neymark, November 1995. "Home Energy Rating System Building Energy Simulation Test (HERS BESTEST) – Volumes 1, Tier 1 and Tier 2 Tests User's Manual." National Renewable Energy Laboratory, Golden, Colorado, Report No. NREL/TP-472-7332.

Results from these six simulation tools were used to determine the acceptance criteria both for Test Case L125A and for the difference between Test Case L100A and Test Case L125A. Table 1 presents the software results along with the acceptance criteria range for Test Case L125A and Table 2 presents the difference results along with acceptance criteria range for the L100A Case minus the L125A Case.

Table F-1. Absolute Results for Case L125A

Heating Results (L125A)		**Cooling Results (L125A)**	
Software Tool	Annual MBtu	Software Tool	Annual MBtu
Tool A	33.72	Tool A	36.07
Tool B	35.31	Tool B	32.11
Tool C	35.58	Tool C	32.60
Tool D	35.62	Tool D	34.31
Tool E	34.21	Tool E	35.47
Tool F	37.40	Tool F	33.40
Mean	35.31	Mean	33.99
StDev	1.29	StDev	1.58
90% CI	1.16	90% CI	1.42
+ Range	**41.40**	**+ Range**	**40.07**
-Range	**29.72**	**-Range**	**28.11**

Table F-2. Difference Results for Case L100A - L125A

Heating Results (L100A-L125A)		**Cooling Results (L100A-L125A)**	
Software Tool	Annual MBtu	Software Tool	Annual MBtu
Tool A	33.70	Tool A	23.96
Tool B	34.09	Tool B	22.89
Tool C	25.30	Tool C	21.15
Tool D	25.66	Tool D	21.40
Tool E	32.53	Tool E	23.08
Tool F	32.50	Tool F	22.10
Mean	30.63	Mean	22.43
StDev	4.04	StDev	1.07
90% CI	3.64	90% CI	0.97
+ Range	**38.09**	**+ Range**	**27.96**
-Range	**21.30**	**-Range**	**17.15**