

## **TASK 2.5.4 DEVELOPMENT OF AN ENERGY SAVINGS CALCULATOR**

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### **ABSTRACT**

California's major energy utilities and the California Energy Commission (CEC) are seeking to allocate capital that yields the greatest return on investment for energy infrastructure that meets any part of the need for reliable supplies of energy. The utilities are keenly interested in knowing the amount of electrical energy savings that would occur if cool roof color materials are adopted in the building market. To meet this need the Oak Ridge National Laboratory and the Lawrence Berkeley National Laboratory (LBNL) have been collaborating on a Public Interest Energy Research (PIER) project to develop an industry-consensus energy-savings calculator. The task was coordinated with an ongoing effort supported by the DOE to develop one calculator to achieve both the DOE and the EPA objectives for deployment of cool roof products. Recent emphasis on domestic building energy use has made the work a top priority by the Department of Energy's (DOE) Building Technologies Program.

The Roof Savings Calculator (RSC) tool is designed to help building owners, manufacturers, distributors, contractors and practitioners easily run complex simulations. The latest web technologies and usability design were employed to provide an easy input interface to an annual simulation of hour-by-hour, whole-building performance using the world-class simulation tools DOE-2.1E and *AtticSim*. Building defaults were assigned based on the best available statistical evidence and can *provide* energy and cost savings after the user selects nothing more than the building location.

A key goal for the tool is to promote the energy benefits of cool color tile, metal and asphalt shingle roof products and other energy saving systems. The RSC tool focuses on applications for the roof and attic; however, the code conducts a whole building simulation that puts the energy and heat flows of the roof and attic into the perspective of the whole house. An annual simulation runs in about 30 sec.

In addition to cool reflective roofs, the RSC tool will simulate high- medium- and low-slope roofs, and has a custom selection for the user whose house has a unique inclination. There is an option for above sheathing ventilation, which is prevalent in tile and stone-coated metal roof assemblies. The tool also accommodates the effects of radiant barriers and low-emittance surfaces in the inclined air space above the sheathing. The practitioner can select to have air-conditioning ducts either in the conditioned space

or in the attic. If in the attic, the user can select one of three air leakage options. Option 1 is an inspected duct having 4% leakage and code level of duct insulation; option 2 is a poorly insulated duct having 14% air leakage; and option 3 is a custom leakage rate specified by the user. The practitioner can setup multiple layers of ceiling insulation.

*AtticSim* is benchmarked against the field data acquired for Ft. Irwin located near Barstow, CA, first as a standalone simulation program and then again integrated within the DOE-2.1E program. The standalone benchmark was very useful to determining how well *AtticSim* replicates the building physics of an attic. The coupled benchmark was useful to verify that the DOE-2.1E/*AtticSim* code is modeling correctly the dynamic relationship between the attic and the occupied space below, as well as the interactions between the attic and the HVAC system, in particular when the ducts are located in the attic.

## **DOE-2.1E**

*DOE-2.1E* [1][2] is a whole-building energy simulation program that was originally developed by Lawrence Berkeley National Laboratory in the early 1980's (Version 2.1A), with continued development through 1993 (Ver. 2.1B through 2.1E) [3]. *DOE-2.1E* is the most current version of *DOE-2* that is in the public domain, although there are later efforts and user-interfaces developed by private companies. Counting all its versions and user interfaces, *DOE-2* is by far the most widely used building energy simulation program in the world today, and has been the basis of most performance-based building energy standards in the U.S. and at least ten other countries, as well as being used for voluntary "Green Building" rating systems such as the US Green Building Council's Leadership in Energy and Environmental Design (LEED).

*DOE-2* itself is an engineering program, with a text-based input and output procedure. The program takes as input a description of the physical building and its space conditioning system, its internal conditions, e.g., schedules for occupancy and lighting, and operations, e.g., thermostat schedules, and the hourly weather conditions, e.g., temperature, humidity, wind speed, and solar radiation, and produces as output the energy consumption, as well as the indoor conditions, of the building. Using the program is difficult because it requires in-depth knowledge both of how *DOE-2* works and how buildings are constructed and operated. Although there are numerous papers attesting to the fundamental soundness of the *DOE-2* program, the fact remains that a computer model is only as good as are the inputs. The multiplicity of inputs can cause confounding results.

*DOE-2* operates on an hourly time-step, and uses *response factors* to model the dynamic heat flows through the building envelope. At the zone level, *DOE-2* uses *weighting factors* (also called *zone response factors*) to model the dynamic response of the space, taking into account its thermal mass or capacitance, heat loss through radiation and or convection. *DOE-2* is made up of two programs, an input processing program called *doebdl* and a simulation program called *doesim*, which is composed of four separate modules called sequentially by *DOE-2.1E*.

## **Module 1. Loads**

The LOADS module simulates the heat flows in and out of the building and calculates the net balance at a fixed reference temperature, negative being interpreted as a heating load and positive as a cooling load.

## **Module 2. System**

The SYSTEMS module takes the results from LOADS, simulates the operation of the HVAC system, and derives the actual zone temperatures, amount of heating and cooling provided by the system, and the energy consumed.

## **Module 3. Plant**

If the building has a central plant, the heating and cooling demands from SYSTEMS are passed to the PLANT module that simulates the energy consumed by the plant to meet the SYSTEMS demands

## **Module 4. Economics**

The ECONOMICS module computes energy costs and is not used in this application.

Although DOE stopped all support for *DOE-2* in 1999, White Box Technologies and others have continued to maintain and even add features to *DOE-2.1E*. For example, Huang [4] added an improved foundation model to the code at the request of the California Energy Commission (CEC). Most recently, LBNL approved making *DOE-2.1E* open source code and White Box technologies announced the creation of an Open Source Center for Building Simulations to maintain the *DOE-2.1E* software for the community of building scientists and practitioners.

## ***Building Models***

For the Web-based Roofing Calculator, four template files have been created for four building input types – residential, medium-sized office, warehouse, and big box retail store. The residential file is adapted from the template file developed by Huang [5] for the *RESFEN* program, a similar easy-to-use program for calculating window energy performance using *DOE-2* as the simulation engine. The three commercial files are adapted from a set of commercial building prototypes first developed in 1990 [5] that later served as the basis for DOE's commercial building benchmark models [6].

These are called template files because they contain numerous *macros*, a feature available in *DOE-2* since the early 1990s that allow the file to be altered based on high-level user inputs set in the Graphical User Interface (GUI). These high-level inputs include building location, vintage, floor area, number of floors, window-to-floor (residential) or window-to-wall (commercial) ratio, and HVAC equipment. As befitting a Roofing Calculator, the user inputs are much more specific for the attic/roof assembly, including the roof construction, cover material, pitch, solar reflectance, and thermal emittance, inclusion of radiant barrier, duct location and characteristics, and ceiling R-value. For a complete list of the user inputs, please refer to later section on Web Deployment.

Once these user inputs have been set, the *macro* statements allow the template file to be modified accordingly.

## **ATTICSIM**

*AtticSim* is a computer tool for predicting the thermal performance of residential attics. The code is publicly available as an ASTM protocol [7]. It mathematically describes the conduction through the gables, eaves, roof deck and ceiling; the convection at the exterior and interior surfaces; the radiosity heat exchange between surfaces within the attic enclosure; the heat transfer to the ventilation air stream; and the latent heat effects due to sorption and desorption of moisture at the wood surfaces. Solar reflectance, thermal emittance and water vapor permeance of the sundry surfaces are input. The model can account for different insulation R-values and/or radiant barriers attached to the various attic surfaces. It also has an algorithm for predicting the effect of air-conditioning ducts placed in the attic, Petrie [8].

Typical construction places ductwork within the attic, which can literally triple the loads for the attic assembly for moderately leaky ducts Petrie [8] and Parker, Fairey, and Gu [9]. Petrie [10] validated the duct algorithm in ASTM C 1340 against experimental data for an attic assembly tested first without and then with a radiant barrier attached to the underside of the roof deck. Validations showed the duct algorithm predicted the duct air change (inlet-to-outlet of the supply duct) within  $\pm 0.3^{\circ}\text{F}$  ( $\pm 0.2^{\circ}\text{C}$ ) over all tests housing an insulated duct system.

*AtticSim* was the subject of an extensive field validation conducted by Ober and Wilkes for ASHRAE [11], which provides mathematical documentation of the code and validation results for low-slope and steep-slope field data collected from seven different field sites. *AtticSim* can simulate a flat roof system as documented and validated in ASHRAE RP 717 (see pg 8-27 and pg 12-2 Joy field data). The code was later validated by Miller [12] for steep-slope asphalt shingle and stone-coated metal roofs. Miller [13] also benchmarked the code against clay and concrete tile and painted metal roof and attic assemblies that exhibit above-sheathing ventilation. Miller [13] was able to predict the heat transfer crossing the air space.

The heat flows at the attic's ceiling, roof section's, gables and eaves are calculated using the thermal response factor technique by Mitalas and Stephenson [14], which requires the thermal conductivity, specific heat, density and thickness of each attic section for calculating conduction transfer functions. *DOE-2.1E* uses a similar technique of response factors (RF) to calculate heat flows through the building envelope, but uses weighting factors (WF) to model the heat gain.

The compatibility of the two sets of procedures and their setup for computing parallel path heat flows was a key hurdle for making *AtticSim* work seamlessly within the "Systems" framework of the *DOE-2.1E* program. White Box Technology made a comparison of the response factors generated by DOE-2 to those used by *AtticSim*. It was found that the two routines computed about the same values the only difference is that DOE-2 starts using the common ratio earlier than does that used by *AtticSim*. Table 1 displays results for the west facing gable roof, Table 1. The ratio of two consecutive response factors is termed the common ratio and it becomes constant after a sufficient number of terms.

As stated *AtticSim* is an ASTM protocol [7] and is publicly available. It has been extensively peer reviewed and benchmarked against field data, and therefore was an excellent candidate for use with the whole building model. *DOE-2.1E* does not adequately describe the radiation exchanges occurring in attics. *AtticSim* does not predict whole building performance. Combined, the two tools would offer a powerful feature that will be benchmarked against field data for CA demonstration homes being collected for the CEC.

**Table 1. Sample Output from DOE-2.1E and *AtticSim* for the conduction transfer functions computed through the insulation path in the gable end of an attic.**

Attic Surface		DOE2.1E Response Factors		
<a href="#">West_facing_gable_insulation_path</a>				
0	0.0659029186	0.0304230750		0.0659029186
1	-0.0236259736	0.0117719891		-0.0236259736
2	-0.0000408221	0.0000408221		-0.0000408221
3	-0.0000001163	0.0000001163		-0.0000001163
COMMON_RATIO	0.0028485756			
Attic Surface		AtticSim Response Factors		
<a href="#">West_facing_gable_insulation_path</a>				
0	0.0659029161	0.0304230732		0.0659029161
1	-0.0236259750	0.0117719903		-0.0236259750
2	-0.0000408222	0.0000408222		-0.0000408222
3	-0.0000001163	0.0000001163		-0.0000001163
COMMON_RATIO	0.0028485769			
<b>Differences between DOE2.1E and AtticSim</b>				
0	-0.0000000025	-0.0000000018		-0.0000000025
1	-0.0000000014	0.0000000012		-0.0000000014
2	-0.0000000001	0.0000000001		-0.0000000001
3	0.0000000000	0.0000000000		0.0000000000
4	0.0000000013			

## Linkage to DOE-2.1E

In the linkage to *DOE-2.1E*, *AtticSim* has been converted to a subroutine that is called in the SYSTEMS module, in effect replacing the TEMDEV subroutine that solves for the zone temperature and calculates the heat gain or extraction provided by the HVAC system. As SYSTEMS loops through the zones, it starts first with the attic, where it will invoke *AtticSim*, and pass to it inputs for the ambient conditions, thermal properties, i.e., response factors, of the surfaces, as well as temperature of the space below and the on-time of the HVAC system from the previous time step. *AtticSim* then returns to *doesim* the attic temperature, the heat flow through the ceiling, and the heat gain or loss to the ducts, which are used by *doesim* to solve for the temperature of the zone below, the heat addition or extraction and finally energy consumption of the HVAC system.

To affect this linkage, numerous changes were also necessary to the input processing *doebdl* program in order to pass the input data from the building model described in *DOE-2*'s Building Description Language (BDL) to *AtticSim*. Some 20 new

keywords have been added, in addition to the “data mining” of the existing *DOE-2* inputs.

## **WEB DEPLOYMENT**

An important objective identified early in development was to maximize the impact of this Public Interest Energy Research (PIER) project by providing a publicly accessible website for comparative simulations of traditional and energy-saving roofing options. This web portal is designed to serve as an industry-consensus roof savings calculator for commercial and residential buildings using whole-building energy simulations (Fig. 1); the managers for the DOE and EPA calculators [15][16] have agreed to take down their calculators prior to full deployment of the Roof Savings Calculator (RSC).

Below we discuss in further detail how objectives of the Project Advisory Committee (PAC) were met, the modern web technologies employed in the development of the calculator, usability considerations, and current functionality.

### **Traceability**

The PAC defined a set of questions and answers that the calculator was to support both in the PAC meeting which convened March 6, 2008 as well as in the PAC quarterly report which was accepted January 21, 2009. In addition, the calculator was to support all relevant capabilities from other calculators while minimizing the number of questions a user must answer. The summary of comparative analysis between these calculators, documents, and the current version of the calculator are listed in Table 2. Input Comparison Chart.









































































The original calculator inputs included all fields listed in Table 2, but subsequent versions were refined by suggestions from teleconference meetings, review Figure 2 and Figure 3. These included the simplification of input by removing days of operation per week, internal load, and HVAC schedule since it was believed that we have fairly accurate data regarding prevalent parameters for these properties as a function of building type and that their presence would allow biased users to report unrealistic savings estimates. *AtticSim* does not support conditioned space under a roof so there is currently no modeling support for an attic-less cathedral roof. The RSC tool answers each of these questions by providing default answers selected from the best available statistics offered by the DOE’s Energy Information Administration (EIA) [18], EPA’s Energy Star [19] Program, and iterative expert review. For additional details, see Appendix A.

### **Technologies**

Many current web technologies were employed in the development of the deployed calculator. The use of dynamic hypertext markup language (DHTML) includes technologies such as HTML and the HTML Document Object Model (HTML DOM) [20], cascading style sheets (CSS) [30], asynchronous JavaScript and XML (AJAX), and the Personal Home Page language (PHP) [22], as well as the jQuery [23] and jQuery User Interface (jQueryUI) Javascript library. The reasoning for employment of these

technologies and their relevance to calculator capabilities, visibility, and maintenance are detailed below.

**Table 2. Input Comparison Chart**

 <a href="http://www.ornl.gov/btc/rsc">http://www.ornl.gov/btc/rsc</a>	RSC <sup>[17]</sup>	PAC Slides	PAC QRpt	DOE <sup>[15]</sup>	EPA <sup>[16]</sup>
Building Type					
Location					
Days of Operation per week					
Building stock					
Cooling system efficiency (SEER)					
Type of heating					
Heating system efficiency					
Duct location					
Level of roof/ceiling insulation					
Above-sheathing ventilation					
Radiant barrier					
Roof thermal mass					
Roof solar reflectance					
Roof solar reflectance (black compare)					
Roof thermal emittance					
Roof thermal emittance (black compare)					
Internal load					
Conditioned space under roof					
Gas and electricity costs					
Inclination / Roof Area					
HVAC Schedule					
Conditioned space (ft <sup>2</sup> )					
Number of floors					
Window-to-wall ratio					

DHTML is the art of making dynamic and interactive web pages. It typically combines HTML, JavaScript, the HTML DOM, and CSS. HTML and the HTML DOM are defined via specifications from the World Wide Web Consortium (W3C). HTML is the predominant markup language for web pages. It allows the use of “tags” (keywords surrounded by angle brackets) to denote structural semantics for a document. The HTML DOM is a cross-platform language-independent convention for interacting with HTML objects and thereby allows all computer types to interact via the internet. HTML DOM allows retrieval and operations on specific elements within the body of a page and is often used closely in combination with CSS.

CSS is a simple mechanism for adding style (e.g. fonts, colors, spacing) to Web documents. This logical separation of content and form through CSS offers several

advantages: editing a single CSS file can make site-wide changes in seconds; logical handles (such as the class, name and id properties of div and span tags) allow precise simultaneous control of particular elements or group of elements; load times are improved due to browser caching and reduction in amount of formatting tags necessary; maintenance capabilities are improved due to cleaner code and separation of concerns; and better search engine placement due to proper HTML structure.

AJAX, coined by Jesse Garret in late 2005, is actually a group of interrelated web development techniques and technologies involving execution on the client-side to create interactive web applications. It allows program-level code to operate within web applications while retrieving data asynchronously from the server without interfering with the display or behavior of the existing page. AJAX was used extensively to provide an interactive web application that shows and hides relevant questions/answers based upon recent selections, updates default values between residential/commercial building types, and allows interactive switching between basic/advanced modes. The JavaScript Object Notation (JSON) lightweight data-interchange format [27] was used for transferring data, such as the formatted list of TMY2 city and states, between server and client. The drawbacks of AJAX include more complex code and thus longer development and maintenance efforts, often improper operation with the “back” button, reduced security, and the ~5% [24] of people who do not have JavaScript enabled for security reasons will be unable to use the dynamic content.

PHP is a general-purpose scripting language typically used to provide dynamic web content. PHP code is used in the calculator to dynamically generate a custom HTML response to the posted user selections and generate the back-end server response which displays energy and cost savings.

jQuery, initially released in 2006 and currently in active development, is a lightweight JavaScript library that facilitates interaction with HTML. It is the most popular JavaScript library in use as of the time of this writing and is used at 20% of the 10,000 largest websites [29]. jQuery allows efficient programming and reduced development times by providing a powerful application programming interface (API) which abstracts away many of the lower-level calls necessary in pure JavaScript. jQueryUI provides access to jQuery’s visual controls and includes several core interaction plugins as well as many UI widgets. jQueryUI’s Accordion widget was used to provide logical groupings of calculator form questions in a way that could be minimized when completed. Additional mouseover tooltips using jQueryUI’s BeautyTips is also planned for future calculator versions. The entire look-and-feel of the calculator was designed using jQueryUI’s ThemeRoller [23] which provides a mechanism for immediately changing the calculator’s look-and-feel based upon a custom, downloaded theme.

## ***Interface Design***

The calculator tool was designed to address several web usability issues [21][25][28]. Consistency is achieved through similar actions and wording required. User selection of radio buttons or entering text of custom values fits common user models. Consistent word phrases were chosen through based upon popularity according to Google search hits which also serves to increase visibility in the relevant domain. The input page is designed to yield closure by dividing the questions into logical groups related to



building properties, heating/cooling, and roof comparison which constitute the beginning, middle, and end of the input process. Simple error handling and inline error message to highlight problematic manual entries is provided. Short-term memory load is reduced by simplified questions, answers, and page organization. Items are made visible only when relevant such as clicking the custom radio button makes the text box visible and also places the cursor in the box for the user to begin typing. Radio buttons, rather than drop-down boxes, were utilized heavily at the expense of screen space since they allow less cognitive overhead (the user is immediately aware of all available choices), label options for radio buttons are clickable to reduce selection time, and radio buttons require fewer and less accurate clicks than drop-down boxes.

The “7 plus/minus 2” principle was followed by organizing the page into essentially three levels: high-level groupings of building, utility cost; less than 7 questions in each of these sections, and relevant subproperties of these questions indented under the appropriate material. The Pareto principle was used to focus users on the subset of options which require input while assigning defaults all others. Fitt’s Law was leveraged by providing immediate accessibility to all options as radio buttons and also making radio button labels clickable. The baby-duck syndrome was utilized by providing simple form input in the form of a short, multiple-choice test.

The Gestalt principle of proximity and similarity are evidenced in the logical grouping of questions; the law of symmetry was the basis for the black roof and white roof comparisons being symmetric across the page center. The calculator was not divided into multiple pages, but collapsible sections, since fold area is important but not crucial. Gloss is provided through mouse-over hints of where question helper links will take the user when clicked. Granularity has been addressed through collaborative reduction of input options. Readability has been enhanced by using web rank determination for question and answer phrasing. Walk-up-and-use design was implemented through page organization to allow a first-time user to quickly and easily run complex simulations. Defaults were set according to the best available statistics for every question except building location, allowing the calculator to be run simply after answering a single question.

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**Policy and International Affairs**

**Solar Energy Technologies**

**Weatherization and Intergovernmental**


## Roof Savings Calculator (RSC)

**Oak Ridge National Laboratory  
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**Introduction**  
The RSC was developed as an industry-consensus roof savings calculator for commercial and residential buildings using whole-building energy simulations. It is built upon the DOE-2.1E engine for fast energy simulation and integrates AtticSim for advanced modeling of modern attic and cool roofing technologies. An annual simulation of hour-by-hour performance is calculated for the building properties provided based on weather data for the selected location. Annual energy savings reported are based upon heating and cooling loads and thus this calculator is only relevant to buildings with a heating and/or cooling unit.

**Roof Savings Calculator**  
To begin, please select from the following options:

**Residential**









**Commercial**



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**Figure 1. Roof Savings Calculator (RSC) Main Page**  
 Web Site at: [www.ornl.gov/btc/rsc](http://www.ornl.gov/btc/rsc)

## Residential Roof Savings Calculator (RSC)

Go to: [Advanced Mode](#)

Building
<p><b>1. Closest location (similar weather):</b> Select location <input type="text"/></p>
<p><b>2. Building Type:</b> Residential <input type="text"/></p>
<p><b>3. Conditioned floor area (ft<sup>2</sup>):</b> ⓘ 2025 <input type="text"/></p>
<p><b>4. Number of floors:</b> 1 <input type="text"/></p>
<p><b>5. Year of construction:</b></p> <p><input type="radio"/> post-1990 <input type="radio"/> 1980-1990 <input checked="" type="radio"/> pre-1980</p>
Heating/Cooling
<p><b>6. Heating equipment:</b></p> <p><input type="radio"/> Electric heat pump <input checked="" type="radio"/> Natural gas furnace <input type="radio"/> Oil furnace</p> <p><b>P1. Electricity price (cents per kWh):</b> ⓘ 11.68 <input type="text"/></p> <p><b>P2. Natural gas price (dollars per 1000 ft<sup>3</sup>):</b> ⓘ 11.65 <input type="text"/></p>
<p><b>7. Heating system efficiency (AFUE):</b> ⓘ</p> <p><input type="radio"/> High-efficiency (90%) <input checked="" type="radio"/> Mid-efficiency (83%) <input type="radio"/> Low-efficiency (70%) <input type="radio"/> Custom</p>
<p><b>8. Cooling system efficiency (SEER):</b> ⓘ</p> <p><input type="radio"/> High-efficiency (15) <input checked="" type="radio"/> Mid-efficiency (13) <input type="radio"/> Low-efficiency (10) <input type="radio"/> Custom</p>

Figure 2. Roof Savings Calculator - 1<sup>st</sup> half

Roof 1 - Existing Roof	Roof 2 - White Roof Comparison
<p><b>9. Roof type:</b></p> <p><input type="radio"/> Tile</p> <p><input type="radio"/> Metal</p> <p><input checked="" type="radio"/> Asphalt shingle</p>	<p><b>18. Roof type:</b></p> <p><input type="radio"/> Tile</p> <p><input checked="" type="radio"/> Metal</p> <p><input type="radio"/> Asphalt shingle</p>
<p><b>10. Solar reflectance (aged 3 yrs):</b></p> <p><input type="radio"/> 60%</p> <p><input type="radio"/> 50%</p> <p><input type="radio"/> 40%</p> <p><input type="radio"/> 30%</p> <p><input checked="" type="radio"/> 20%</p> <p><input type="radio"/> 10%</p>	<p><b>20. Solar reflectance (aged 3 yrs):</b></p> <p><input type="radio"/> 60%</p> <p><input checked="" type="radio"/> 50%</p> <p><input type="radio"/> 40%</p> <p><input type="radio"/> 30%</p> <p><input type="radio"/> 20%</p> <p><input type="radio"/> 10%</p>
<p><b>11. Thermal emittance (aged 3 yrs):</b></p> <p><input type="radio"/> Acrylic Al-Zn coated steel (15%)</p> <p><input type="radio"/> Bare Al-Zn coated steel (20%)</p> <p><input type="radio"/> Metallic field-applied coating (50%)</p> <p><input type="radio"/> Painted steel (85%)</p> <p><input checked="" type="radio"/> Other materials (90%)</p>	<p><b>21. Thermal emittance (aged 3 yrs):</b></p> <p><input type="radio"/> Acrylic Al-Zn coated steel (15%)</p> <p><input type="radio"/> Bare Al-Zn coated steel (20%)</p> <p><input type="radio"/> Metallic field-applied coating (50%)</p> <p><input type="radio"/> Painted steel (85%)</p> <p><input checked="" type="radio"/> Other materials (90%)</p>
<p><b>12. Above-sheathing ventilation:</b></p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>	<p><b>22. Above-sheathing ventilation:</b></p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>
<p><b>13. Pitch (rise:run):</b></p> <p><input type="radio"/> High (slope &gt; 8:12)</p> <p><input checked="" type="radio"/> Medium (2:12 &lt; slope ≤ 8:12)</p> <p><input type="radio"/> Low (slope ≤ 2:12)</p>	<p><b>23. Pitch (rise:run):</b></p> <p><input type="radio"/> High (slope &gt; 8:12)</p> <p><input checked="" type="radio"/> Medium (2:12 &lt; slope ≤ 8:12)</p> <p><input type="radio"/> Low (slope ≤ 2:12)</p>
<p><b>14. Radiant barrier present:</b></p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>	<p><b>24. Radiant barrier present:</b></p> <p><input type="radio"/> Yes</p> <p><input checked="" type="radio"/> No</p>
<p><b>15. Attic insulation (hr ft<sup>2</sup> °F per Btu):</b></p> <p><input type="radio"/> R-50</p> <p><input type="radio"/> R-38</p> <p><input type="radio"/> R-19</p> <p><input checked="" type="radio"/> R-11</p> <p><input type="radio"/> R-7</p> <p><input type="radio"/> R-5</p> <p><input type="radio"/> R-3</p> <p><input type="radio"/> None</p>	<p><b>25. Attic insulation (hr ft<sup>2</sup> °F per Btu):</b></p> <p><input type="radio"/> R-50</p> <p><input type="radio"/> R-38</p> <p><input type="radio"/> R-19</p> <p><input checked="" type="radio"/> R-11</p> <p><input type="radio"/> R-7</p> <p><input type="radio"/> R-5</p> <p><input type="radio"/> R-3</p> <p><input type="radio"/> None</p>
<p><b>16. Duct location:</b></p> <p><input type="radio"/> Conditioned space</p> <p><input checked="" type="radio"/> Attic</p>	<p><b>26. Duct location:</b></p> <p><input type="radio"/> Conditioned space</p> <p><input checked="" type="radio"/> Attic</p>
<p><b>17. Duct leakage:</b></p> <p><input type="radio"/> Inspected (4%)</p> <p><input checked="" type="radio"/> Uninspected (14%)</p>	<p><b>27. Duct leakage:</b></p> <p><input type="radio"/> Inspected (4%)</p> <p><input checked="" type="radio"/> Uninspected (14%)</p>

Calculate



[ORNL disclaimer](#) [LBNL disclaimer](#)

Figure 3. Roof Savings Calculator - 2<sup>nd</sup> half

## **CALCULATOR BENCHMARK**

The 2003 F.W. Dodge [26] report shows tile roofs comprise 30% of the new and retrofit roof markets in CA. We therefore conducted field experiments in Southern California to benchmark both *AtticSim* as a stand alone tool and the new RSC tool. *AtticSim* has a history of validations against several different profiles of tile, stone-coated metal, asphalt shingle and standing seam metal roofs, all of which were field tested at ORNL. However, *AtticSim* was also benchmarked against two of the Ft Irwin homes to assist White Box Technology with its benchmark of the RSC tool.

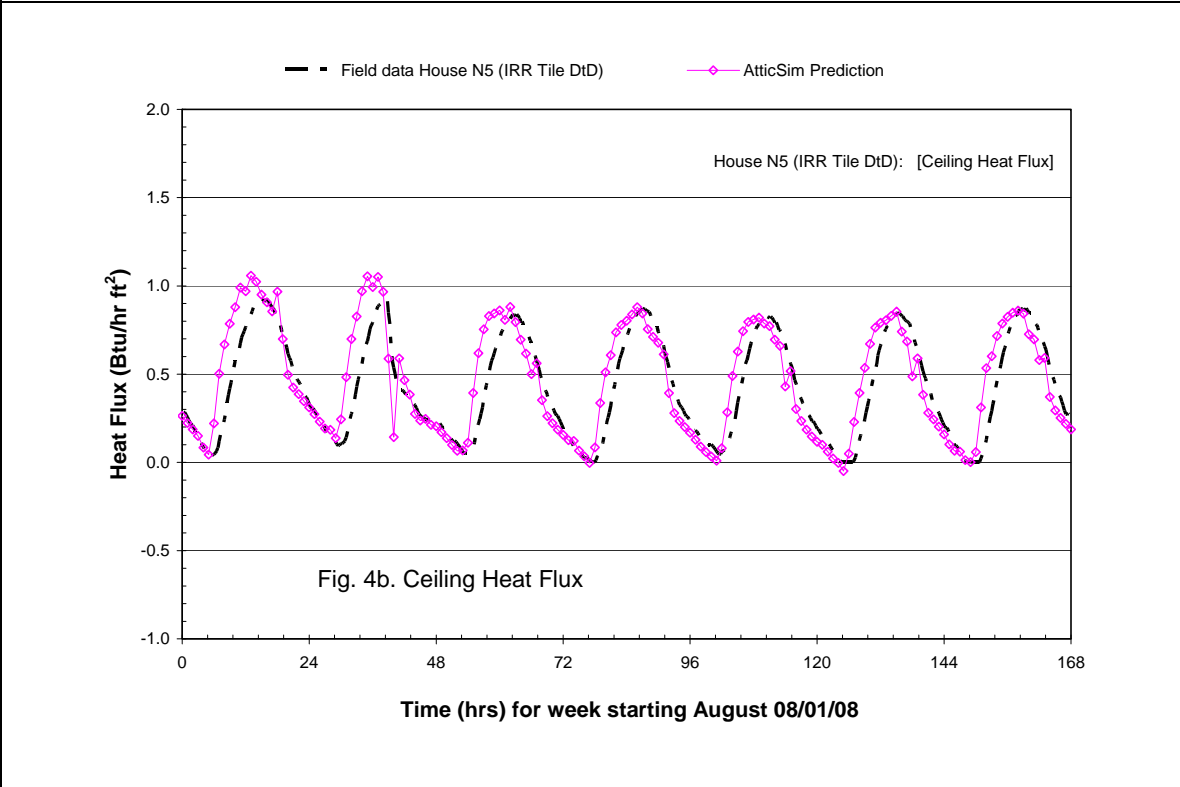
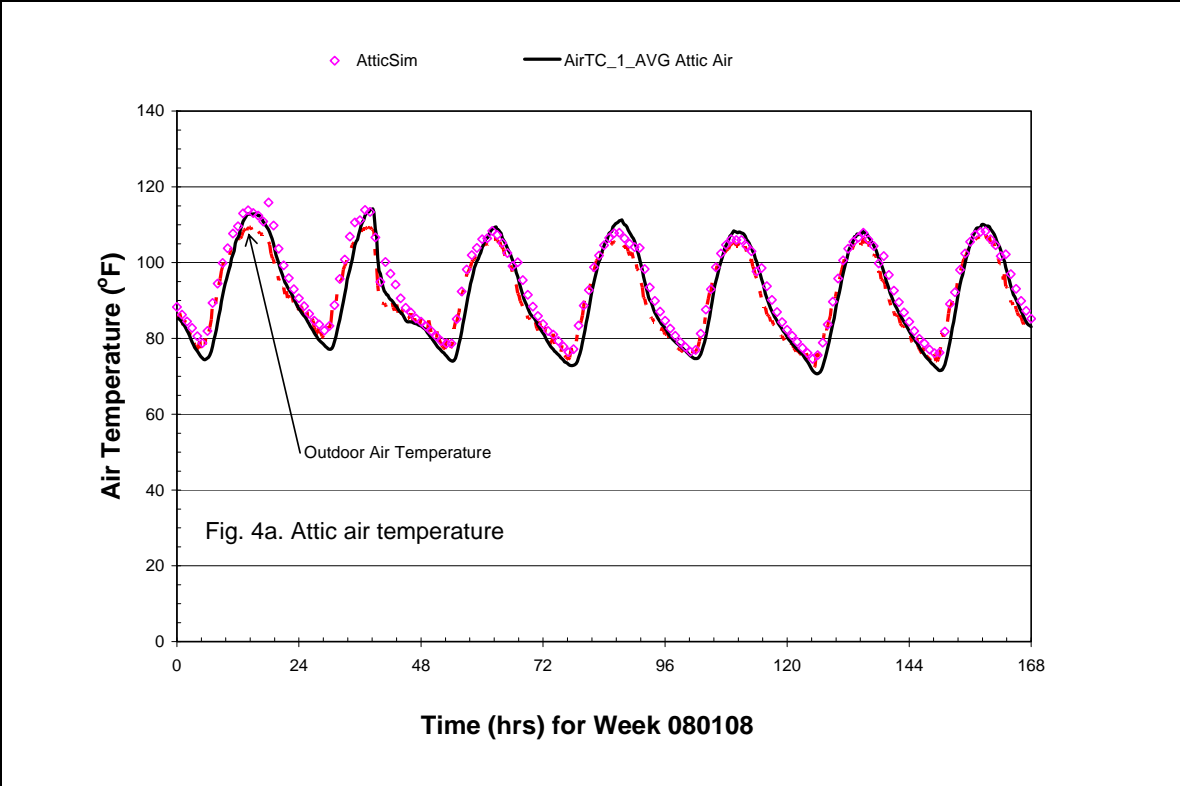
The four demonstration homes were setup for making two bases of comparison: 1) concrete tile applied directly to the deck, one coated with a cool color coating the other not coated, and 2) concrete tile elevated 1½-in (0.038-m) above the deck, one roof coated with a cool color coating the other not coated. *AtticSim* was benchmarked against House N5 for summer data (Aug. 2008) and House N8 for winter data (Feb 2008). During these periods tenants were paid a \$200 per month incentive to keep their thermostats at 72°F (22.2°C). House N5 has the tile attached directly to the deck (labeled D-t-D) with the tile painted with COOLTILE IR COATINGS™ by American RoofTile Coatings. House N8 had conventionally painted the tile placed on double battens (labeled DB).

### ***AtticSim* Benchmark of House N5**

The solar irradiance from pyranometers fixed to the sloped roof surfaces, and the weather data were used by *AtticSim* to compute the surface temperature of the tile, the air temperature in the inclined air space made by the tile, the heat flux crossing the roof decks, the attic air temperature and the heat flow crossing the attic floor. Measured temperature at the thermostat was also used by *AtticSim* to estimate convection effects from the ceiling into the conditioned space.

Estimates had to be made of the airflow induced by a solar fan installed on the south facing roof. All homes had these fans which energized whenever the photovoltaic panel generated enough current to drive the fan. However, results show that *AtticSim* simulated the attic air temperature within about  $\pm 2^\circ\text{F}$  (0.6°C), Fig. 4a.

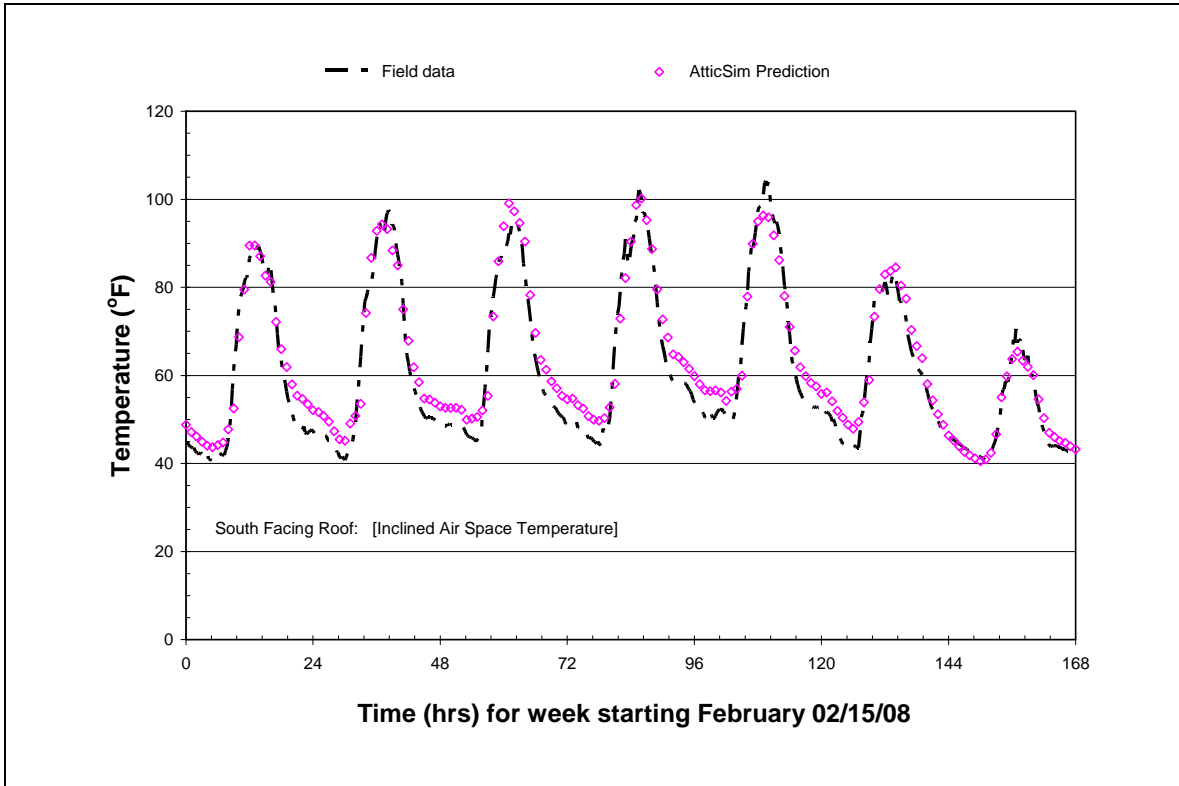
The heat flux crossing the south facing roof deck was accurately computed by *AtticSim* as compared to the flux measured by heat flux transducers (installed on underside of roof deck). Figure 4b shows that *AtticSim* was also able to follow the diurnal trends in heat flows crossing the attic floor having  $R_{\text{US}} 38$  ( $R_{\text{SI}} 6.7$ ) fiberglass batt insulation. The peak day values between *AtticSim* and measured ceiling heat flows are within about 5% of measure; however, measured data lags *AtticSim* predictions and is believed due to the truss system in the attic. Additional simulation work will be conducted to check whether the truss system affects the predictions.



**Figure 4. The attic air temperature (4a) and the heat flows through the south-facing roof deck (4b) for House N5 having cool color tile laid directly to the deck.**

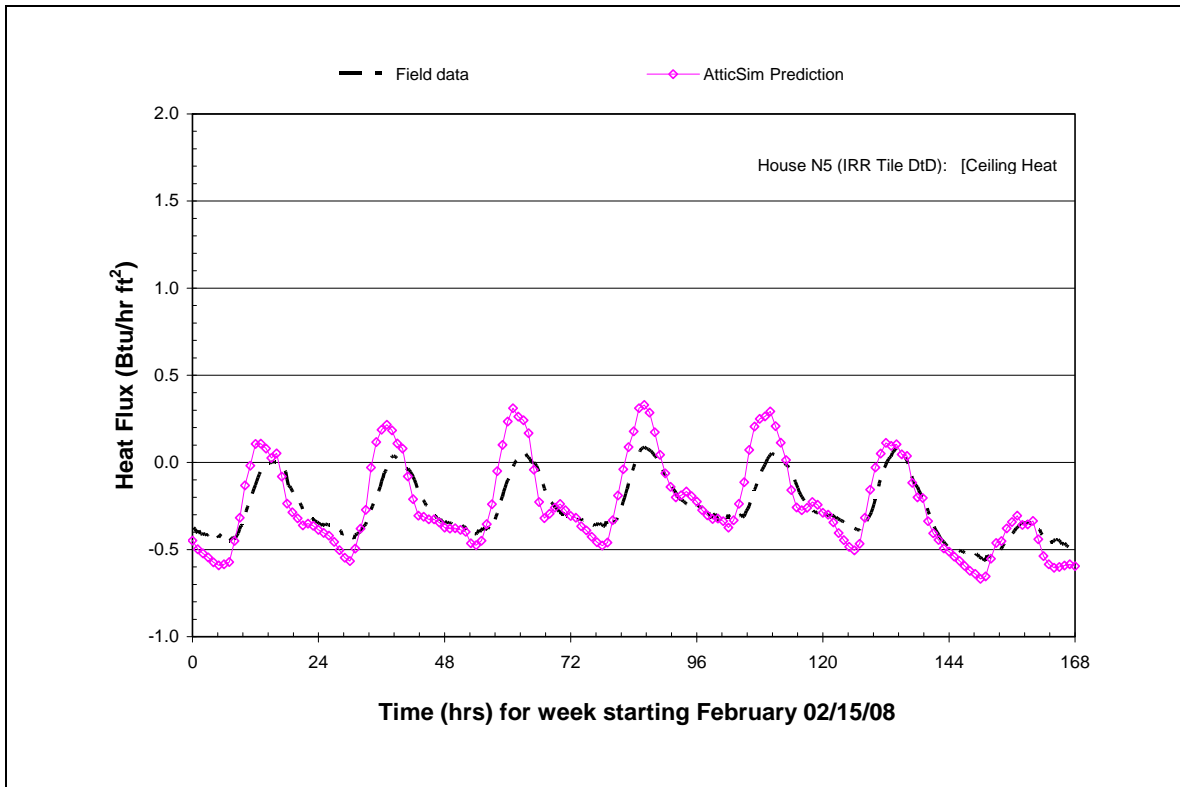
## AtticSim Benchmark of House N8

The air temperature in the inclined air space formed by the double batten arrangement of the concrete tile is shown in Figure 5 for data collected during February 2008. Again the solar irradiance was input *AtticSim* from pyranometers fixed to the sloped roof surfaces, and the weather data were used in *AtticSim* to compute the thermal performance of the roof and attic. The code well replicated the measured air temperature in the ventilated space under the tile. Miller et al. [12] provide details of the energy balance for interior duct flow that is used to compute the air temperature in the air space.



**Figure 5. The air temperature in the inclined air space under the concrete tile is predicted to within  $\pm 2^{\circ}\text{F}$  ( $0.6^{\circ}\text{C}$ ) of the field data for House N8 having conventionally painted tile placed on double battens.**

For this February week of data, the outdoor air temperature peaks at about  $68^{\circ}\text{F}$  ( $20^{\circ}\text{C}$ ) during the day and drops to about 50 to  $40^{\circ}\text{F}$  ( $10$  to  $4.4^{\circ}\text{C}$ ) at night. Therefore the ceiling heat loads are relatively small and did not exceed  $\pm 0.5$   $\text{Btu}/(\text{hr ft}^2)$  [ $0.16$   $\text{W}/\text{m}^2$ ]. Yet results show that *AtticSim* simulated the daily trends in ceiling heat flux relatively well, Fig. 6. During the daytime the predicted and measured flux are not accurate and differ by about  $0.25$   $\text{Btu}/(\text{hr ft}^2)$  [ $0.08$   $\text{W}/\text{m}^2$ ]. This occurs because the temperature difference across the  $R_{\text{US}} 38$  ( $R_{\text{SI}} 6.7$ ) batt insulation is at best only  $3.6^{\circ}\text{F}$  ( $2^{\circ}\text{C}$ ), while at night the temperature drop across the ceiling insulation is about  $14.4^{\circ}\text{F}$  ( $8^{\circ}\text{C}$ ). Therefore the error is primarily due to the uncertainty of the temperature measurements.



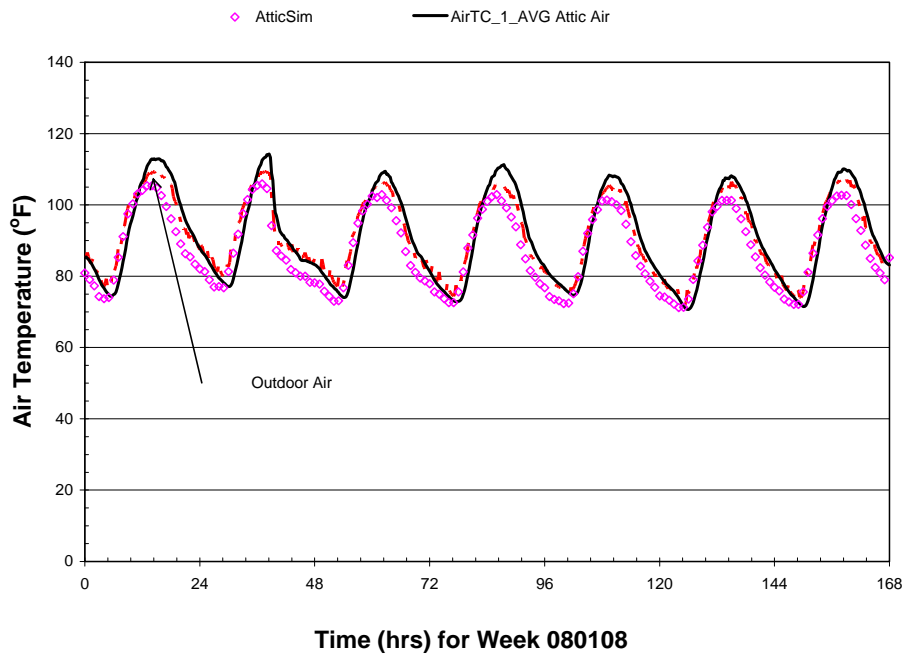
**Figure 6. The ceiling heat flux computed by *AtticSim* and benchmarked against the field data for House N8 having conventionally painted tile placed on double battens.**

### ***DOE-2.1E/AtticSim Benchmark of Houses N5 and N8***

We repeated the simulations described above for House N5 using the August 08 week of field data and for House N8 using the February 08 data with the combined DOE-2.1E/*AtticSim* code. Testing determined whether *AtticSim* worked properly within DOE-2.1E for the thermal exchange through the attic floor (i.e., house ceiling) and for the data exchange about HVAC operations and duct losses. Both of these issues are complex, since they are nonlinear as well as interrelated. The heat flows through the attic floor, which are critical for determining the energy savings from attic conservation measures, are further complicated by the fact that DOE-2 uses several sequential steps to derive net zone heat flows, so that in coupling DOE-2 with *AtticSim* it has been necessary to disable some of these steps to prevent double counting. To calculate the duct losses, *AtticSim* needs to know the on-time for the HVAC system, but that is not known until further into the simulation process. Ultimately, it was found necessary to model the attic twice, once with DOE-2 and then again with *AtticSim*.

Figure 7 is similar to Figure 4a, but this time showing the attic air temperatures modeled with the combined DOE-2/*AtticSim* program rather than with the standalone *AtticSim* program.

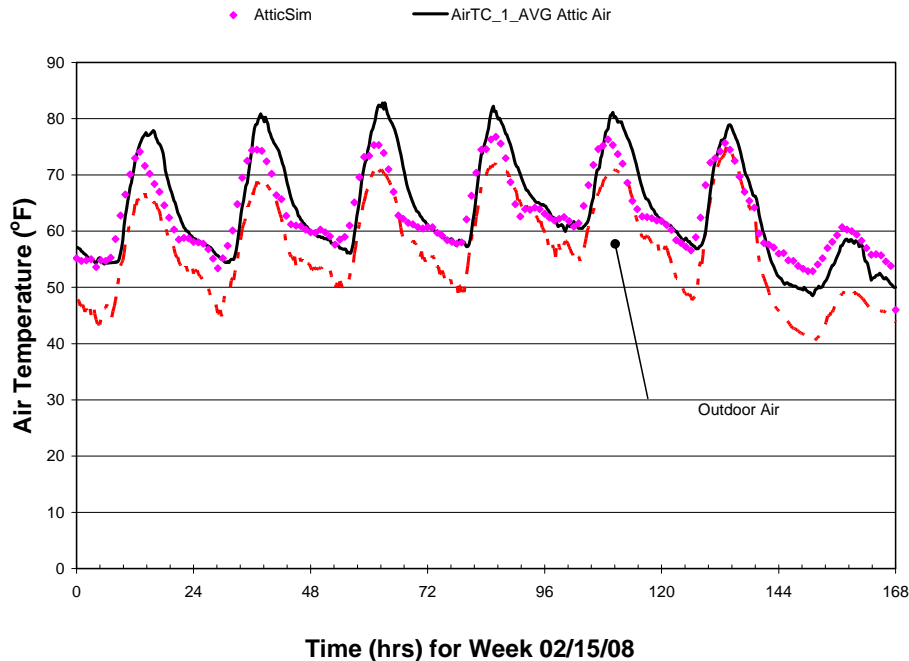




**Figure 7. Comparison of DOE-2.1E/AtticSim to measured attic temperatures for House N5 collected August 08.**

In comparison to Figure 4a, the attic temperatures shown by the combined DOE-2.1E/AtticSim code are lower. This may be due to either differences in how the attic is being modeled as compared to the standalone AtticSim simulation, or to double-counting of ceiling heat flows in the draft version of the DOE-2.1E/AtticSim program.

Figure 8 shows the attic air temperatures modeled with the combined DOE-2/AtticSim program for House N8 as compared to measured data field data for February 08. Here again the attic temperatures shown by the combined DOE-2.1E/AtticSim program matches the measured minima, but are consistently several degrees lower than the daily maxima. This again may be due to double-counting of ceiling heat flows in the draft version of the DOE-2.1E/AtticSim program.



**Figure 8. Comparison of DOE-2.1E/AtticSim to measured attic temperatures for House N8 collected February 2008.**

## CONCLUSIONS

In conclusion, the RSC [17] provides an approachable portal for both industry experts and residential homeowners to leverage the best available whole-building energy simulation packages and determine energy and cost savings for modern roof technologies and related retrofits. The managers of the DOE and EPA calculators have agreed to take down their calculators and refer all users to a single universally acceptable energy estimating tool.

The tool uses the DOE-2.1E whole-building energy simulation program and calls *AtticSim* from the SYSTEMS module where *AtticSim* computes the temperatures and heat flows of all surfaces in the attic and passes back to DOE-2.1E the attic air temperature, the duct gains and losses and the ceiling heat flow. For all simulations the attic floor is assumed sealed with no air leakage crossing from the conditioned space into the attic. The two codes merged together run an annual simulation in about 30 sec.

Combined, the two codes offer in the RSC a powerful feature that was benchmarked against field data for CA demonstration homes collected at Ft Irwin. Hence, the tool was shown to yield credible results and the new tool is a real-time calculator (loaded on the internet).

## ACKNOWLEDGEMENTS

Funding for this project was provided by the California Energy Commission's Public Interest Energy Research program through the U. S. Department of Energy under contract DE-AC03-76SF00098. Oak Ridge National Laboratory is managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725. The

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## **DISCLAIMERS**

Mention of the trade names, instrument model and model number, and any commercial products in the manuscript does not represent the endorsement of the authors nor their employer, the Oak Ridge National Laboratory or the US Department of Energy.

## **NOMENCLATURE**

AJAX	Asynchronous JavaScript and XML
API	application programming interface
CSS	Cascading Style Sheets
DHTML	Dynamic HyperText Markup Language
DOE	Department of Energy
DOM	Document Object Model
EPA	Environmental Protection Agency
HVAC	Heating Ventilation and Air Conditioning
JSON	JavaScript Object Notation
PHP	Personal Home Page
PVC	polyvinylchloride thermoplastic membranes
PIER	Public Interest Energy Research
RSC	Roof Savings Calculator
SR	solar reflectance
TE	thermal emittance
R <sub>US</sub>	Thermal resistance (hr ft <sup>2</sup> °F) per Btu
R <sub>SI</sub>	Thermal resistance (m <sup>2</sup> K) per Watt

## **RECOMMENDATIONS**

Sensitivity runs are needed to judge the stability of the new tool's solution procedure. Therefore, it is recommended to continue using the demonstration data for Ft Irwin and also for Northern CA in Redding to complete a unique benchmark of the RSC tool that few whole building codes have documentation to distinguish their code's credibility. The RSC tool also requires beta testing by the roofing community.

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# APPENDIX A

Joint teleconferences were hosted by Joshua New with all stakeholders regarding design decisions, web layout, appropriate questions and default values, order of energy-efficient options, and other implementation-level issues. The meeting minutes regarding the final form and justifications for the calculator design are provided below.

## Meeting #1 Minutes

### *Meeting Minutes*

**Date:** November 19, 2009  
**From:** Joshua R. New (newjr@ornl.gov), 3147, Room 210, MS 6070, 865-241-8783  
**Subject:** [RSC] Roof Savings Calculator - Meeting Minutes #1 (Addressed)

### **I) Meeting #2 Schedule (12/14/09-12/18/09):**

Please take a minute to complete the Doodle poll by *\*Sunday, December 13\** by selecting the dates and times that are convenient for you:

<http://www.doodle.com/gs7fh5a9xxk3zn3z>

Note: The final meeting time will be sent the morning of Monday, December 14

### **II) Roof Savings Calculator 0.2 link:**

The latest version for discussion purposes and feedback from colleagues can be found at:  
<http://www.cs.utk.edu/~new/rsc2/rsc.htm?mode=adv>

Note: Commercial questions are denoted C1, Residential questions are denoted R1, Simple-mode questions are denoted S1, and Advanced-mode questions are denoted A1

All feedback should be directed to:  
Joshua New, ORNL – [newjr@ornl.gov](mailto:newjr@ornl.gov)

### **III) Meeting Minutes (11/12/09)**

#### **1) Invitees**

DOE: Marc LaFrance ([Marc.Lafrance@ee.doe.gov](mailto:Marc.Lafrance@ee.doe.gov))  
ORNL: Andre Desjarlais ([desjarlaisa@ornl.gov](mailto:desjarlaisa@ornl.gov))  
Bill Miller ([millerwal@ornl.gov](mailto:millerwal@ornl.gov))  
Joshua New ([newjr@ornl.gov](mailto:newjr@ornl.gov))  
WhiteBox: Joe Huang ([yjhuang@whiteboxtechnologies.com](mailto:yjhuang@whiteboxtechnologies.com))  
Ender Erdem ([ender.erdem1@gmail.com](mailto:ender.erdem1@gmail.com)) - recently retired LBNL  
LBNL: Ronnen Levinson ([RML27@cornell.edu](mailto:RML27@cornell.edu))  
Haley Gilbert ([hegilbert@lbl.gov](mailto:hegilbert@lbl.gov))

Concordia: Hashem Akbari ([HAkbari@ENCS.Concordia.CA](mailto:HAkbari@ENCS.Concordia.CA))  
CEC: Chris Scruton ([Cscruton@energy.state.ca.us](mailto:Cscruton@energy.state.ca.us)) - absent  
Norman Bourassa ([Njbouras@energy.state.ca.us](mailto:Njbouras@energy.state.ca.us))  
EPA: Steven Ryan ([Ryan.Steven@epamail.epa.gov](mailto:Ryan.Steven@epamail.epa.gov)) - absent  
Neelam Patel ([Patel.Neelam-R@epamail.epa.gov](mailto:Patel.Neelam-R@epamail.epa.gov))

## 2) Action Items

- a) **Color codes** (Word document attached for anyone using mail clients without HTML/color support):  
Change (blue)  
Addition (green)  
Advanced mode (brown)  
Phase II possibility (red)

- b) **Calculator link** of version being referenced by Meeting Notes:  
<http://www.cs.utk.edu/~new/rsc1/bec.htm?calc=Com>

### c) **Meeting Notes:**

#### Meeting Info:

- Marc LaFrance recommended
  - Monthly Meetings (Doodle meeting planner link at top)
- Marc LaFrance recommended an alpha version release and feedback (Norman Bourassa concurred based on previous work)
  - An updated version, with link, will be made available before the next meeting and can be shared with others
  - A SurveyMonkey link will be provided for gathering feedback

#### General:

- Change name to: Roof Savings Calculator
- Support for more building types (Office-20%, Warehouse-14%, and School-13% originally chosen based on percentage of national footprint). Joe Huang stated offices, warehouses, schools, and stores are same building characteristics as used by PNNL in support of ASHRAE-90.1
  - Participants opted to substitute Box Stores for schools
  - Options for more building types is a Phase II initiative

#### 1. Closest location

- Ronnen Levinson and Hashem Akbari suggested zip code location instead of TMY2 drop-down
  - Support for zip code or map location is a Phase II initiative

- 2. Conditioned area (ft<sup>2</sup>):
- Ronnen Levinson suggested rephrasing to
  - 2. “Conditioned floor area...”
  
- 4. Window-to-wall ratio:
- Joe Huang recommended eliminating 4. Number of Windows
- Andre Desjarlais recommends adding default
  - Will be relegated to advanced mode
  
- 5. Building Stock:
- Pre-1980
- 1980-1990
- Post-1990
  
- 6. Internal load and 7. Days of Operation per week:
- Joe Huang proposed adding “6. Internal load” and “7. Days of Operation” to advanced mode
  - Will be relegated to advanced mode
  
- 8. Type of heating:
- Haley Gilbert suggested no cooling as an option
  - Support for internal temperatures (for 3<sup>rd</sup> world countries) is a Phase II initiative
  - Directions will be given to inform user this tool is only for residences with a cooling unit
  
- 8. Type of heating:
- Bill Miller suggested
  - Rewording as “Type of heat/cool unit”
  
- 9. Heating system efficiency (SEER):
- Ronnen Levinson and Hashem Akbari suggested
  - HSPF (Heating Seasonal Performance Factor ) for Heating performance
  - SEER (Seasonal Energy Efficiency ratio) for Cooling performance
  
- 9. Heating system efficiency (SEER):
- Bill Miller suggested furnace efficiency for gas furnace
  - Will replace question 9 accordingly
  
- 9. Heating system efficiency (HSPF) and 10. Cooling system efficiency (SEER):
- Marc LaFrance suggested
  - “advanced”, “standard”, and “old” mode
  - Numbered efficiencies relegated to advanced mode
  
- 11. Duct location:



- Hashem Akbari recommended “No ducts” and Marc LaFrance “ductwork above roof plane”. *AtticSim* does not model ductwork above the roof, Hashem Akbari has a model that could serve as a basis for this extension.
  - Ductwork above the roof plane is a Phase II initiative

#### 13. Gas price (cents per therm):

- Ronnen Levinson pointed out units are different between cents-per-therm in the calculator and USD-per-1k-cubic-feet in link
  - Consistent units between question and web price reference will be used
- Norman Bourassa and Haley Gilbert recommended
  - Question mark/links opening in another window

#### 15. Level of insulation:

- Ronnen Levinson recommended R-50 (with hyphen) to clarify units
  - Rus-50 will be utilized having units [hr ft<sup>2</sup> oF per Btu]

#### 17. Inclination (rise/run):

- Ronnen Levinson rise:run (rather than rise/run) and Hashem Akbari concurred
  - Rise:run will be used

#### 18. Thermal mass:

- Ronnen Levinson and Bill Miller discussed various commercial roof types: Thermoplastic membranes (TPO,PVC), Bitmens (asphalt), Built-up roof (BUR), Pavers (concrete), and Ballasted Roofs
  - All will be added in cool roof section as roof type
  - Options for ballast roof is a Phase II initiative (porous media not modeled by *AtticSim*)

#### 18. Thermal mass:

- Norman Bourassa recommended rephrasing to
  - Roof thermal mass

#### 20. Solar reflectance and 21. Thermal emittance:

- Hashem Akbari recommended custom solar reflectance and emittance
  - “Other” button will be added

#### Others:

- Norman Bourassa recommended
  - (Commercial version roof grouping): “Plenum/Roof – Your building”
- Norman Bourassa recommended ASV be changed to offset mounting
  - Will use “offset mounted roof” (with help introducing the ASV work from ORNL)

- Marc LaFrance recommended keeping offset mounting (to promote the technology) rather than removing it
  - Accepted
  
- *Calculate button*
- Joe Huang working to refine output, Hashem Akbari asked if it would give peak demand
  - Outputs will include: heating and cooling load for summer and winter, dollar annual savings for heating and cooling, and peak demand
  
- *Pricing models*
- Support only for utility rates will be utilized
  - Other pricing models (such as on-peak and off-peak pricing) is a Phase II initiative

## Meeting #2 Minutes

**Date:** December 19, 2009  
**From:** J. R. New (newjr@ornl.gov), 3147, Room 210, MS 6070, 865-241-8783  
**Subject:** [RSC] Meeting #2 - Addressed

### I) Meeting #3 Schedule (1/20/10):

Teleconference date: Wednesday, Jan. 20th  
 Teleconference start time: 3:00-4:00pm EST (12:00 noon – 1:00pm PST)  
 Dial-in (toll-free) number: (866) 564-1870  
 Confirmation number: 4558717  
 Based on doodle availability: <http://www.doodle.com/8uteaa77su3r7x8n>

### II) Roof Savings Calculator (v0.3) link:

The latest version for discussion purposes and feedback from colleagues can be found at:  
<http://www.ornl.gov/btc/rsc>

All feedback should be directed to:  
 Joshua New, ORNL – [newjr@ornl.gov](mailto:newjr@ornl.gov)

### III) Meeting Minutes (12/15/09)

#### 1) Invitees

DOE: Marc LaFrance ([Marc.Lafrance@ee.doe.gov](mailto:Marc.Lafrance@ee.doe.gov)) - present  
 ORNL: Andre Desjarlais ([desjarlaisa@ornl.gov](mailto:desjarlaisa@ornl.gov))

Bill Miller ([millerwal@ornl.gov](mailto:millerwal@ornl.gov))  
Joshua New ([newjr@ornl.gov](mailto:newjr@ornl.gov)) - present  
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## 2) Action Items

- a) **Color codes** (Word document attached for anyone using mail clients without HTML/color support):  
Change Implemented or Suggestion Accepted (blue)  
Suggestions for discussion (red)

- b) **Calculator link** of version being referenced by Meeting Notes:  
<http://www.cs.utk.edu/~new/rsc3/rsc.htm?calc=res#mode=adv>

Current calculator link:  
<http://www.ornl.gov/btc/rsc>

- c) **Meeting Notes/Status Update:**

The last teleconference was near the holiday break and mostly involved high-level discussion of calculator purpose and functionality. Below are recorded calculator suggestions, changes, and reasons for those changes.

### To-Do List:

1. PHP script processing of form data into macro for execution of 2 simulations via engine calls
2. Busy cursor or progress bar (recommended for any process taking longer than 1 or 2 seconds, respectively) during simulation runs
3. Outputs will include: heating and cooling load for summer and winter, dollar annual savings for heating and cooling, and peak demand
4. Output should incorporate building/input conditions
5. Joe Huang working to refine simulation output
6. Scalability analysis – maximum number of concurrent users
7. Mouse-over question mark for helpful definitions or pictures, click for website/more info

Internal Changes (discussions between Joshua New, Bill Miller, Joe Huang, and Ender Erdem):

- Semi-permanent link for latest version of the calculator hosted on ORNL servers: <http://www.ornl.gov/btc/rsc>
- New main/index page and graphics
- Extended cross-compatibility (proper operation by browsers other than Internet Explorer) by using [W3C's Validation Service](#) to take the Roof Savings Calculator page from 64 errors and 254 warnings to 6 errors and 0 warnings.
- PHP script was written that takes the posted form data and writes them back to the user with the beginnings of an animated gif progress bar
- Residential and Commercial calculators renumbered with A# for advanced questions but otherwise dynamic and consistent as the user would expect
- Simple and Advanced mode options at top fully operational
- Collapsible subsections (comparisons collapse together)
- Labels (and not just radio buttons) are clickable
- Indented sections introduced for additional relevant details
- Residential/Commercial title displayed at top is dynamic to let the user know which version they're using
- Drop-down for building type allows easy switching between the Residential and Commercial versions of the calculator
- "Other" radio buttons sometimes only available in advanced mode and clicking makes visible the corresponding text box with cursor ready for typing
- Cascading Style Sheets, CSS-based "look-and-feel" of the website, are adjustable based upon [jQuery UI's ThemeRoller](#). The curious or artistically minded should feel free to play at the web link above and send me your downloaded theme as an option for the appearance of the Roof Savings Calculator.
- Several calculator defaults set according to values used in:
  - Akbari and Konopacki, 2005. Calculating energy-saving potentials of heat-island reduction strategies. *Energy Policy* (33), pp. 721-756, tables 1-3.
  - Levinson and Akbari. 2009. [Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants](#). *Energy Efficiency*, DOI 10.1007/s12053-008-9038-2.

Meeting Info:

- Marc LaFrance recommended:

- Meeting the last full week of each month (January moved to week before the ASHRAE conference)
- Marc LaFrance recommended alpha release:
  - Planned alpha-release as soon as the front-end is integrated with the simulation engine and back-end display of simulation results; however, the current front-end (<http://www.ornl.gov/btc/rsc>) can be shared with colleagues with feedback directed to Joshua New ([newjr@ornl.gov](mailto:newjr@ornl.gov)).

General:

3. Conditioned area (ft<sup>2</sup>):

- Default to 2025 as the average square foot of homes built between 1973 and 2008 (link next to RSC question #3)

4. Number of floors:

- Joe Huang recommended:
  - 2 floors default for residential (currently 1)

A1. Window-to-wall ratio:

- Joe Huang recommended
  - 14.5 for residential, 40.0 for commercial
  - Window-to-wall differences for office, warehouse, and box store differences
  - Units? (window-to-wall [currently] or window-to-sq ft conditioned area)

5. Building Stock:

- Ronnen Levinson recommended
  - “Building Stock” -> “Year of construction”

A2. Internal load and A3. Days of Operation per week:

- Joe Huang proposed:
  - Removing “A2. Internal load” and “A3. Days of Operation” due to assumed schedules
  - Schedule/usage profiles a Phase II initiative

6. Type of heating:

- Ronnen Levinson recommended:
  - Renaming to “Heating equipment”
  - Renaming options to “natural gas furnace” and “oil furnace”

6.P2. Gas price (cents per therm):

- Ronnen Levinson suggested
  - Renaming to “natural gas price”
  - Renaming options to dollars instead of USD

#### 7-8-8. Heating and Cooling system efficiency (HSPF, AFUE, SEER):

- Ronnen Levinson suggested
  - AFUE for furnaces, HSPF for heat pump
  - Spelling out AFUE/HSPF/SEER acronyms (links added next to question for spelling out acronym in tooltip and link to webpage with more info)
  - Answers not parallel/similarly-phrased: changed from advanced, mid-, standard, pre-1992 to high-, mid-, and low-efficiency
  - SEER low- (10) and mid-efficiency (13) based upon [EERE page](#) and [DOE press release](#)
  - SEER high-efficiency changed to 15 based upon [qualification for the US EPA Energy Star label](#)

#### Attic/Plenum/Roof:

- Attic/plenum/roof sections reordered working from outside of the building inward
- Default comparison Residential: 20% asphalt to 50% reflective metal roof; Commercial: 20% bitumen to 50% reflective TPO/PVC

#### 9/19. Roof Type:

- Ronnen Levinson recommended:
  - "cool roof membranes (TPO/PVC)" -> "single-ply membrane"
  - "pavers (concrete)" -> "concrete paver"
  - "bitumen (asphalt)" -> "modified bitumen"
  - "Built-up Roof" -> "built up"

#### 10/20. Solar reflectance:

- Ronnen Levinson recommended:
  - "solar reflectance" -> "aged solar reflectance"
  - Changed to Solar reflectance (aged 3 years)
  - Tooltip to convert from manufacturer's initial number to an aged number; based on experiments at ORNL's ESRA facility
- Defaults for solar reflectance based on type
- Reduction in number of options
- Other boxes only visible in Adv mode

#### 11/21. Thermal emittance:

- Ronnen Levinson recommended:
  - "thermal emittance" -> "aged thermal emittance"
  - Changed to Thermal emittance (aged 3 years)
  - Tooltip to convert from manufacturer's initial number to an aged number; based on experiments at ORNL's ESRA facility
  - Default values of:
    - 0.15 (acrylic-coated galvalume steel)
    - 0.20 (bare galvalume steel)

- 0.50 (metallic field-applied coating)
- 0.85 (painted steel)
- 0.90 (anything else)
- Changed to the following (to avoid endorsing specific vendor products):
  - Acrylic Al-Zn coated steel (15%)
  - Bare Al-Zn coated steel (20%)
  - Metallic field-applied coating (50%)
  - Painted steel (85%)
  - Standard materials (90%)
- Other boxes only visible in Adv mode

13/23. Pitch (rise:run):

- Ronnen Levinson recommended:
  - "inclination (rise:run)" -> "pitch"
  - "steep slope (>8:12)" -> "high (slope > 8:12)"
  - "conventional slope (4:12-8:12)" -> "medium (2:12 < slope <= 8:12)"
  - "low slope (2:12-4:12)" -> "low (slope <= 2:12)"
  - delete "flat roof"
  - Different defaults/nomenclature for residential vs commercial

14/24. Radiant barrier:

- Ronnen Levinson recommended:
  - Renaming to “Radiant barrier present:”

15/25. Level of insulation:

- Ronnen Levinson asks:
  - Is this the thermal resistance of the roof assembly, or the thermal resistance of insulation in the roof assembly? Rename "level of insulation" -> "thermal resistance"
  - Renamed to “Attic insulation”
- Reduction in number of insulation options
- Other boxes only visible in Adv mode

16/26. Duct location:

- Moved to Attic section as potential option in deep retrofit

17/27. Duct leakage:

- Other boxes only visible in Adv mode

Phase II Initiatives:

- Options for more building types
- Support for zip code or map location for location selection
- Support for internal temperatures (for 3<sup>rd</sup> world countries)
- Ductwork above the roof plane
- Options for ballast roof (porous media not modeled by *AtticSim*)

- Other pricing models (such as on-peak and off-peak pricing)
- Cost-effectiveness analysis for optimum return-on-investment
- Schedule/usage profiles a Phase II initiative