

ASSESSMENT OF COMMONLY-USED CODE COMPLIANCE SIMULATION SOFTWARE RELATIVE TO COLD FORMED STEEL FRAMING

Introduction and Objectives

Energy code adoption and enforcement has traditionally lagged behind structural, fire, and other life safety issues. In some ways, cold formed steel (CFS) framing has benefited from this time lag since codes have not been particularly good at addressing the unique heat transfer issues with CFS. Even in the cases where codes have attempted to keep current through modification in the way CFS is addressed, many communities are still working off versions of codes that predate these modifications.

The International Residential Code (IRC) and International Energy Conservation Code (IECC) are the most widely recognized codes governing energy efficiency in U.S. buildings. Prescriptive methods for energy efficiency in the IECC and IRC are not highly favorable to cold-formed steel framing, especially in multi and single-family buildings. However, each of these codes offers a performance approach that allows users to trade off certain prescriptive requirements if they can be made up elsewhere. For example, if foam insulation is required on the exterior of walls or under trusses, a designer or builder could theoretically eliminate the foam and add more insulation in the attic, or upgrade the windows.

The use of the performance approach requires simulations to be run with “approved” simulation tools. We use the term “approved” loosely, since there are a number of organizations that certify, review, or otherwise assess software, but no single approval process. Building officials and designers most often look to the U.S. Department of Energy (DoE), Energy Star, RESNET, or states like California for guidance on software tools.

On one hand, it is encouraging that the software industry is healthy and competitive as evidenced by over 300 software tools listed in DoE’s directory of simulation tools (http://www.eere.energy.gov/buildings/tools_directory/). On the other hand, the sheer number of options can be intimidating. Fortunately, a group of simulation tools has risen to the top as the most widely-used and recognized in the United States. These include:

1. REM Design, available from Architectural Energy Corporation at around \$400, depending on options purchased.
2. REScheck, a free download from the U.S. DoE
3. Energy 10, distributed by the Sustainable Building Industry Council. Single user license available for \$325.
4. Energy Gauge (residential), available for \$149 from the Florida Solar Energy Center

5. Energy Pro. A CA Title 24 compliance tool available from Global Dodd/Energy Soft Inc. for \$450.

This assessment focuses on the first four simulation tools above. Future assessments may be undertaken to address EnergyPro and other California specific tools, as well as more sophisticated emerging tools such as EnergyPlus.

Energy Plus, a free download from the U.S. DoE, combines the best features of DOE2 and BLAST, two sophisticated tools frequently used by researchers or when the interest is in a more detailed evaluation of a building. DOE2 is also the engine behind many other less complicated tools including Energy Gauge.

Unfortunately, interface tools for Energy Plus are still developing and its use is limited at this point. However, it may become an important tool in the future and SFA may need to examine it if it starts to make market penetration.

This study will focus on determining how these tools assess CFS in their simulations. Questions we will attempt to answer include:

1. How many CFS configurations are addressed in their libraries?
2. Can libraries be modified to include missing configurations?
3. Which methods are used to determine U-Values and/or effective R-Values employed by the software for CFS?
4. Are framing factors (i.e., percent of assembly that is framing compared to gross wall area) addressed appropriately with regard to CFS?
5. Which codes and editions are covered by the software?
6. Does the software employ a UA alternative approach, a reference-home based performance approach, or both?
7. What are the plans for updates?

Findings of the assessments

During this study, it became clear that there is much confusion and/or a lack of consensus over which method is most appropriate for computing the effective R- and U-Values for a steel framed assembly. We suggest readers of this report first study the appendix for a discussion of the various methods and other definitions prior to reading the rest of this report.

REM Design

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Description

The following description is from the REM Design Help file:

REM Design is user-friendly, yet highly sophisticated, residential energy analysis and code compliance software developed specifically for the needs of home builders, architects, code officials, and weatherization programs. REM Design calculates heating, cooling, hot water, lighting, and appliance energy loads, and consumption and costs for new and existing single and multi-family homes. Climate data is available for cities and towns throughout North America.

REM Design operates in Windows and has many unique features, including a Simplified Inputs procedure, extensive component libraries, automated energy efficient improvement analysis, duct conduction and leakage analysis, latent and sensible cooling analysis, lighting and appliance audit, as well as active and passive solar analysis.

REM Design is based on seasonal simulations as opposed to hourly or daily methods used in more sophisticated tools. It checks compliance with an extensive list of codes and standards including ASHRAE 90.2, the International Energy Conservation Code (IECC) and a variety of state codes. For the IECC, it addresses the UA and performance compliance paths. It also reports heating, cooling, appliance and lighting, and domestic hot water consumption, loads, and costs based on a home's design and construction features. It matches locations with climate data and allows a user to input energy prices or select default values. REM Design simulates single or multi family homes, duplexes, townhouses, or apartments.

The same simulation engine that drives REM Design is also used for REM Rate, a related simulation tool AEC developed specifically for Home Energy Raters. REM Design and REM Rate are recognized by DoE and RESNET and thus are likely to be acceptable tools by local code officials. The assessment that follows is based on a review of REM Design Version 12. Unless otherwise stated, references to the IECC refer to the 2006 edition.

Library files and inputs

The windows platform results in an easy to use, menu-driven input process. Users can select a simplified approach where defaults are used for items like lights and appliances, or a more complex option. With either option, a user is

offered a library of components. For example, in the windows section, typical windows are provided along with corresponding U-Values and solar heat gain coefficients (SHGC).

For CFS assemblies, the only wall specifically referenced as a steel frame in the library is a 2x4 wall with R-11 in the cavity. However, there is an option to select other R-Values and then modify it from the default wood wall to a standard steel frame wall. So in effect, REM Design does appear to cover quite a few CFS wall configurations. It is just not very obvious to the beginning user that assemblies beyond the R-11 standard steel wall are accessible. There are no library selections for steel floors or roof/ceiling assemblies, or ways to convert a wood floor or roof assembly to CFS.

Table 1 below shows the lone steel wall assembly in REM Design’s library including the effective U-Value used in the simulations. It also shows the results of switching an R-13 wood selection to a standard steel wall selection. The last column is the total effective R-Value and is shown to illustrate the relative difference between the cavity R and the value that correlates with the Effective U-Value.

Component	Cavity R-Value	Effective U-Value	Effective R-Value
Steel 2x4	R-11	0.121	8.3
Steel 2x4	R-13	0.117	8.5

Table 1. Wall Framing Characteristics with 23% framing factor
Source: REM Design Materials Library

The intent of REM Design is for the values in the table above to represent a wall assembly after adjustment for framing factors (described later in this review). Note that this is different than the clear wall values often cited in test reports or codes. For comparison purposes, test results on steel walls with R-11 would yield an R of at most 7.9 before accounting for framing beyond the studs and track (i.e., a clear wall assembly), according to the 1995 AISI Thermal Design Guide. Thus, the lone library entry for a steel wall with R-11 insulation would appear to overestimate the effective R-Value. This discrepancy is attributed to the method used by REM Design in calculating the R- and U-Values as discussed in the next section of this review.

Calculation of CFS U- or R-Values

The following paragraph taken from the help section of REM Design describes the methodology behind the calculation of the thermal resistance, R-Value, employed by the software.

When Standard Steel Frame is selected, the software will automatically apply a correction factor to the R-Value of the cavity insulation to account for the high conductivity of the steel framing. The correction factors are taken from Table 502.2.1.1.1 in Chapter 5 of the 2003 IECC. As an example, for a steel stud 2 x 4 wall with 16" o.c. construction and R-13 cavity insulation, the insulation R-Value of the cavity insulation would be multiplied by a factor of 0.46, resulting in an effective R-Value of 5.98.

REM Design uses a parallel path method calculation using two paths – one through the metal and one through the center of cavity. They attempt to address the influence of steel on the cavity insulation by applying a factor to the cavity insulation obtained from the 2003 IECC. Discussions with the AEC, the software developer, indicate that the parallel path method used to determine a U-Value for an assembly can be manipulated to input any U-Value the user desires. Thus, one could use a trial and error process to input a U-Value more in line with the modified zone method that is generally accepted as more accurate for CFS thermal calculations.

Framing factors

REM Design offers two methods for inputting U-Values. The first method is a “quick fill” approach that allows a user to define the framing factor or to use the REM Design default of 23% for a framed wall. The program calculates a U-Value based on the framing factor and R-Values of the various components of the wall assembly.

In the second option, REM Design allows the user to apply a parallel path approach to effectively build a component U-Value based on the assembly’s layers and their respective R-Values. The user inputs an area of coverage for each path in the assembly, which is basically equivalent to setting a framing factor.

As mentioned previously, one downside of this approach is that it does not correct for the thermal conductivity of steel in accordance with the modified zone method. However, the user can obtain good results if he or she knows what the effective U-Value is and can manipulate the parallel path until the target U-Value is obtained. This would assume the user conducts a modified zone calculation to obtain the target U-Value using actual or default framing factors.

Planned updates

There are two large updates of REM Design released annually. Minor updates are released on an as needed basis to compliment the larger releases. The material libraries are not generally updated. AEC believes they are user friendly

and pretty much will stay that way until the company gets enough feedback to change them. The company is very open to any comments or suggestions to improve their software. Usually, once the software is purchased, the majority of their users add additional materials as needed, so the company has not been forced into keeping an up-to-date material library.

Conclusions on REM Design

REM Design has attempted to address the disconnect between the actual performance of steel and the methods used to calculate its performance. The developers used a parallel path correction based on correction factors in the 2003 IECC for custom inputs. REM Design then applies a framing factor that, in effect, double counts the framing to an extent since the IECC requirements already assume some (unknown) framing factor.

Further, the product libraries are in need of extension expansion, since they only address an R-11 wall at this point. CFS walls with R-13 and R-19 cavity insulation, floors with R-19, and roof/ceiling assemblies with R-30, 38, and 49, and variations of these assemblies with continuous insulation should be specifically named in future releases.

Even in the case where user inputs based on the modified zone method are used to address the U-Value of steel, the user has to manipulate the software through a trial and error process. Inclusion of the modified zone method in REM Design would eliminate the need for this manipulation and for prior hand calculations. Further, an entry that allows a user to bypass the parallel path method altogether and simply enter a U-Value for the assembly would be helpful.

REScheck

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Description

The following excerpt is from the REScheck Help file:

The software demonstrates compliance with the 1992, 1993, and 1995 editions of the MEC, the 1998, 2000, 2003, and 2006 editions of the IECC, the 2006 International Residential Code (IRC), and the following state and county residential codes: Arkansas, Georgia, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Vermont, Wisconsin, and Pima County, Arizona. The software enables you to quickly compare different insulation levels in different parts of your building to arrive at a package that works best for you. A report that can be submitted with your building plans for plan review is automatically generated.

The REScheck software program was developed to simplify and clarify code compliance with the Model Energy Code (MEC), the International Energy Conservation Code (IECC), International Residential Code, and a number of state codes. REScheck allows their users the option of simulating either residential detached one and two family homes or multifamily buildings.

The REScheck program is different from a purely performance tool like REM Design or Energy Gauge in that it does not look as comprehensively at whole building performance. Rather, REScheck offers their users the choice of performing an overall UA (total heat loss through the building envelope) approach or a high efficiency equipment tradeoff approach to demonstrate compliance.

The UA approach is based on the thermal conductance of each building component. The overall building UA is the equivalent of the thermal U-Value multiplied by the component surface area. If the total heat loss through the envelope does not exceed the total heat loss from the same building designed to code, the software states that the building meets code and passes.

The high efficiency equipment trade off option allows users to look at improvements in the heating and air conditioning systems and trade these off against a lower building UA.

The following REScheck software assessment was based on Version 4.1.0 released in June 2007.

Library files and inputs

A windows based operating system allows the user to easily input building data using a menu driven process. Each section allows the user to choose from pull down menu component libraries or input user defined data. Users enter information for items on three menus – Project, Envelope, and Mechanical.

The Project menu includes location (city, state) as well as building characteristics (one or two family) data for the building. The Envelope menu includes

characteristics for walls, ceilings, floors, skylights, windows, doors, basement, and crawl space. The Mechanical section allows the user to enter furnace, boiler, heat pump, or air conditioner data. The Mechanical section is considered optional, allowing the user to input mechanical equipment inputs only when completing the high efficiency equipment tradeoff approach. Water heaters are not part of the trade-off analysis.

For steel framed wall assemblies, REScheck does not specify the thickness of steel or the depth of the wall used. Rather, REScheck’s material library includes steel framed assemblies with studs at either 16” or and 24” on center. Cavity insulation is assumed to have an R-Value of 13 to result in the U-Values and Effective R-Values shown in Table 2.

Material	Cavity R- Value	U-Value	Effective R-Value
Steel framing 16”	R-13	0.114	8.8
Steel framing 24”	R-13	0.100	10

Table 2. Wall Framing Characteristics
Source: REScheck Materials Library

For steel framed floor assemblies, REScheck offers the user two steel framing options where the floor type is any 16” o.c. or 24” o.c. floor assembly that contains C-shaped members. Using an assumed R-19, the resulting U-Values and effective R-Values for various floor assemblies are illustrated in Table 3.

Material	Cavity R- Value	Effective U-Value	Effective R-Value
Steel framing 16” o.c.			
2x6	R-19	0.058	17.2
2x8	R-19	0.094	10.6
2x10	R-19	0.094	10.6
2x12	R-19	0.094	10.6
Steel framing 24” o.c.			
2x6	R-19	0.053	18.9
2x8	R-19	0.081	12.3
2x10	R-19	0.081	12.3
2x12	R-19	0.081	12.3

Table 3. Floor Framing over outside air or unconditioned space
Source: REScheck Materials Library

For steel framed roof/ceiling assemblies, REScheck offers three steel framing options – steel truss, 16 inch on center joist/rafter, or 24 inch on center joist/rafter. Examples of the resulting R- and U-Values based on an assumed R-30 in the attic are shown in Table 4.

Material	Cavity R-Value	Effective U-Value	Effective R-Value
Steel Truss	R-30	0.038	26.3
Steel Joist/Rafter 16" o.c.			
2x6	R-30	0.039	25.6
2x8	R-30	0.047	21.3
2x10	R-30	0.102	9.8
2x12	R-30	0.102	9.8
Steel Joist/Rafter 24" o.c.			
2x6	R-30	0.036	27.8
2x8	R-30	0.043	23.3
2x10	R-30	0.082	12.2
2x12	R-30	0.082	12.2

Table 4. Roof/Ceiling Framing Characteristics
Source: REScheck Materials Library

Calculation of CFS U or R-Values

The REScheck software follows a parallel path calculation method to CFS wall assemblies, using correction factors from the 2003 IECC applied to the cavity insulation. Unlike REM Design, however, REScheck uses a single path through the center of the cavity after applying the correction factor to obtain a component or effective R-Value. The inverse of this results in an effective U-Value.

As with walls, REScheck calculates the floor component using a single path through the center of the cavity portion of the assembly. The method sums the sheathing R-Value, the cavity insulation R-Value multiplied by the IECC correction factor, air films, and gypsum R-Values to obtain an effective R-Value.

The method to determine an R-Value for CFS ceiling joists is the same as used for walls and floors. For CFS roof trusses, a higher correction factor of 0.864 is applied to the cavity insulation.

Framing Factors

The REScheck software does not directly address framing factors. Rather, the developers use two different correction factors for 16 or 24 inch stud spacing based on the 2003 IECC Tables 502.2.1.1.1. The IECC factors inherently contain some framing factor, but it is unknown what the code assumed. A review of the code change proposals and accompanying documentation leading up to the 2003 IECC publication may uncover the assumed factors.

Planned Updates

Generally, there are two major updates of the REScheck software released annually. The latest version 4.1.0 was released in June 2007.

Conclusions on REScheck

The REScheck software uses a parallel path calculation method for estimating R-Values for cold-formed steel walls. The use of a single path through the center of cavity, after applying a correction factor to the cavity insulation R-Value, is derived from the 2003 IECC.

Further, the determination of an Effective R-Value in REScheck comes with inherent framing factors assumed in the 2003 IECC code for 16 and 24 inch on center stud spacing. These may or may not be the appropriate framing factors since agreement on appropriate values has always been a point of controversy in code development. ASHRAE and others are pushing higher factors than in the past and any changes would impact the REScheck calculations for CFS and other materials.

The materials library in REScheck is extensive and most standard CFS assemblies are represented. The materials library also offers the user the option to modify or create new steel configurations as the CFS industry expands and more framing options become available.

Because REScheck is not a whole building performance model, the opportunities it represents for tradeoffs are basically limited to increasing or decreasing R-Values in different parts of the home (e.g., increasing wall insulation to allow a decrease in crawl space insulation) or using higher efficiency equipment to make up for lower R-Values somewhere in the thermal envelope.

Energy 10

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Description

A description extracted from the Energy 10 help file states the following:

ENERGY-10 is a conceptual design tool for low-energy buildings. It is the software component of a project called Designing Low-Energy Buildings with ENERGY-10, which is being conducted for the U.S. Department of Energy (DOE). The program does hour-by-hour simulations for a typical year. Daylighting, passive solar heating, and low-energy cooling strategies are integrated with energy-efficient shell design and mechanical equipment.

The Energy 10 Software is an hourly simulation tool resulting from collaboration between the Sustainable Buildings Industry Council (SBIC), Lawrence Berkley National Laboratory, the Berkeley Solar Group, and NREL Center for Building and Thermal Systems. Energy 10 calculates an overall building UA to determine if a building meets code. It is applicable to a variety of building types including commercial, residential, and industrial.

The following software assessment was based on Version 1.8 that checks for compliance with the 2004 release of ASHRAE 90.1.

Library files and inputs

The Energy 10 software is a menu driven, MS Windows based system. A tab called "Buildings" is used to input building components including walls, floors, roofs, HVAC systems, lighting, infiltration, and other characteristics. A second tab for "Internal gains" is used for water heaters.

The Energy 10 software library features two walls constructed with steel studs. These are called "steelstud 4" and "steelstud 6 poly." "Steelstud 4" is a 4-inch wall and "steelstud 6 poly" is a 6-inch wall that includes 2 inches of exterior foam insulation.

Every material in the materials library has default values for physical properties (material conductivity and specific heat) that are used for calculations. Using the properties of each steel member from the materials library and the software's internal method for calculating an effective R-Value yields the results in Table 5.

Material	Cavity R-Value	Effective R-Value
Steelstud 4	13	R-8.1
Steelstud 6 poly (Cavity insulation plus 2 inches of continuous insulation)	18	R-19.2

Table 5. Energy 10 Steel Wall R-Values
Source: Energy 10 Material Library

For steel floor assemblies, Energy 10 offers the user three steel options in the library. The three options are called “steel”, “steelstud”, and “steelstud 2.” Using these steel options and corresponding default floor characteristics, simulations were run to obtain effective R-Values for the various floor framing options as shown in Table 6.

Material Name	Cavity R- Value	Effective R-Value
“Steel”		
2x4 frame*	19	R-9.05
2x8 frame	19	R-9.50
2x10 frame*	19	R-3.23
2x12 frame	19	R-9.05
“Steelstud”		
2x4 frame*	19	R-11.44
2x8 frame	19	R-12.63
2x10 frame*	19	R-10.99
2x12 frame	19	R-11.44
“Steelstud 2”		
2x4 frame*	19	R-11.44
2x8 frame	19	R-12.63
2x10 frame*	19	R-10.99
2x12 frame	19	R-11.44

* Original floor framing types in library

Table 6. Floor Framing Characteristics
Source: Energy 10 Simulation on Sample Project Building 1

The Energy 10 software offers the user three attic ceiling joist options - “steel”, “steelstud”, or “steelstud 2.” These are the same materials as used for floor assemblies. For roof/ceiling assemblies, there are many construction options to choose from ranging from attic to cathedral to flat to pv-roof. A selection of typical residential and commercial assemblies is shown in Table 7. These values were simulated using Energy 10 sample building defaults.

Material/Cavity R-Value	Effective R-Value
Attic/R-30	
Steel	R-28.85
Steelstud	R-29.05
Steelstud 2	R-29.05
Attic /R-60	
Steel	R-59.67
Steelstud	R-59.86
Steelstud 2	R-59.86
Cathedral 2x10/R-30	
Steel	R-27.43
Steelstud	R-27.56
Steelstud 2	R-27.56
Flat/R-38	
Steel	R-37.99
Steelstud	R-38.48
Steelstud 2	R-38.48
Flat/none	
Steel	R-3.81
Steelstud	R-4.07
Steelstud 2	R-4.07
Flat/R-19	
Steel	R-18.90
Steelstud	R-19.40
Steelstud 2	R-19.40
Flat/R-6	
Steel	R-6.15
Steelstud	R-6.65
Steelstud 2	R-6.65

Table 7. Roof/Ceiling Framing Characteristics
Source: Energy 10 Simulation on Sample Project Building 1

Note that roof truss configurations are not addressed in Energy 10.

Calculation of CFS U- or R-Values

The Energy 10 software uses a wall construction based on two parallel heat flow paths. The Energy 10 Help Menu states the following:

In ENERGY-10, these two walls are represented by two parallel heat-flow paths, one through a pseudo-material called "steelstud," which is a smear of steel and fiberglass that represents the zone of influence of the thin steel web. The properties of "steelstud" and its width were taken from the ASHRAE zone-method calculation. The resulting overall R-Values agree

with detailed two-dimensional heat-flow calculations from the Oak Ridge National Laboratory.

The Energy 10 Help Menu defines how the software calculates the wall R-Value in the following excerpt:

The wall R-Value is calculated by $1/U$, where U is the area-weighted average of the U-Values of the two sections. The wall R-Value is a calculated composite number that accounts for independent parallel heat flow through the two sections. The U-Value is displayed for each of the layers, including air films (inside or outside surfaces) and within the wall cavity. The U-Values are defined under the Materials library, which is the only place the values can be modified.

Once R-Values are tabulated for each path - one through the stud section and one through the center of cavity - a weighted average is performed based upon the non-framed section's gross wall area.

The Energy 10 software calculates the effective R-Value for floor and roof assemblies following the same method as for walls.

Framing factors

Energy 10 does not allow a user to input framing factors. Rather, the developers assumed a 20% framing factor that is used as a default in the simulations. This framing factor is applied regardless of the assembly, including to walls, floors, and roof/ceiling assemblies.

Planned updates

According to SBIC, there are no updates currently in the process. The newest Version 1.8 was released in June 2005. SBIC does not produce updates on a regular schedule but on an as needed basis.

Conclusions on Energy 10

Energy 10 has the most extensive wall, floor, and ceiling joist libraries of all of the software programs evaluated. It addresses multiple configurations of cold-formed steel and allows for an unlimited number of user defined new configurations. However, it does not offer any options for roof trusses.

The developers claim that the method used to determine Effective R-Values and U-Values is based on work performed by Oak Ridge National Laboratory, which

implies that they use the modified zone method. The descriptions of the method in the software are consistent with this implication. If so, then Energy 10 is the only simulation tool we assessed that is treating steel correctly from this perspective.

One area for improvement in the R-Value calculation methods would be to allow the user to define the framing factor. Energy 10 uses a default framing factor of 20% in its current form.

Energy Gauge USA

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Description

The following description is from the Energy Gauge Help file:

Energy Gauge USA is a multifunction residential building tool. The standard version, ResSim, includes DOE2.1E simulation for design of low-energy buildings and evaluation of hourly peak demand impacts. It also determines compliance with the International Energy Conservation Code (IECC-1998/IECC-2000, Chapter 4 of the 2003 IECC, and Section 404 of the 2004 IECC and 2006 IECC) and includes a System Sizing feature that calculates whole house heating and cooling loads. The Pro version, ResSim Pro, adds pollution analysis, Improvement Analysis and a Tax Credit Summary Report that provides qualification criteria for Energy Policy Act of 2005 tax credits. The rating version, ResRate Pro, includes all of the above plus HERS rating capabilities.

Energy Gauge simulations are performed on either a single family or multi family residence, dependent upon the number of stories in the building. A commercial version also is available but it only addresses the Florida Building Code.

When Energy Gauge software checks compliance with the IECC, it employs both the UA alternative approach and a reference-home based performance approach. Under the reference-home based approach, the Energy Gauge

passes the home if the annual energy usage is equal to or less than the IECC reference home.

The following assessment was based on Version 1.8 of the Energy Gauge software package released in June 2006.

Library Files and Inputs

The windows based operating system allows the user to input building data using the two main sections in Energy Gauge USA - Project Search and Project Notebook. Project Search is the entry window that is seen every time the program is started. It allows the user to gain access to the project database and allows the user to create new projects, open existing projects, or exit the program.

Project Notebook is the primary work area where the user enters project and building data. Each project in the database has its own Notebook. Each Notebook includes Site, Envelope, and Equipment tabs with a total of 20 building sections. By clicking onto a section tab, the user can input or view information describing the building component.

For steel framed wall assemblies, Energy Gauge offers the user a choice for steel framing from the drop down menu. Within this option, the user can create an unlimited number of variations by inputting values for wall cavity insulation, insulation grade, framing fraction, sheathing, and solar absorptance. The R-Value, framing fraction, and insulation grade are used to compute an effective U-Value for the wall assembly. For example, an R-13+5 wall would yield an effective R-Value of 18.18.

For steel framed floor assemblies, Energy Gauge offers the choice of crawlspace, raised floor, or floor over garage. The user can create an unlimited number of floor assemblies by inputting values for cavity insulation R-Values, insulation grade, sheathing R-Values, and flooring (i.e. carpet, vinyl/wood, or tile) which will result in an effective floor U-Value. Using the “frame – steel” with an assumed R-19 cavity insulation R-Value, Energy Gauge would yield an effective U-Value of 0.051 or an effective R-Value of 19.61.

For steel framed roof/ceiling assemblies, Energy Gauge offers a choice of wood or metal ceiling trusses. The user chooses the ceiling location from a choice of cathedral, knee wall, or under attic. Once the user defined inputs are entered for R-Value and insulation grade, the software calculates a resulting effective U-Value for the ceiling. For example, with a cavity insulation of R-38, Energy Gauge would yield an effective U-Value of 0.025 or an effective R-Value of 40 on the “frame – steel” assembly.

Calculation of CFS U- or R-Values

EnergyGauge calculates the thermal resistance for all assemblies using the parallel path method. Walls and ceilings are broken into their framed and non-framed segments which are modeled as two distinct parallel heat flow paths. These sections are separated into their material layers which are evaluated based on their physical properties of thickness, thermal conductivity, density, and specific heat. Calculations are performed to yield R-Values for each path. The two R-Values are then weighted based on a framing factor.

Framing Factors

Energy Gauge uses a default framing factor of 23% for standard framing. It also gives the user the option of inputting a custom framing factor. For advanced framing techniques, the developers offer guidance for component framing factors as shown in Table 8.

Component	Spacing	Framing Fraction
Wall	Advanced Framing	
	16 o.c.	0.19
	24 o.c.	0.16
Floor	Advanced Framing	
	16 o.c.	0.11
	24 o.c.	0.08
Roof/Ceiling	Advanced Trusses ("raised heel")	
	16 o.c.	0.10
	24 o.c.	0.07
	Conventional	
	16 o.c.	0.13
	24 o.c.	0.09
Roof	Advanced Trusses ("raised heel")	
	16 o.c.	0.10
	24 o.c.	0.07
	Conventional	
	16 o.c.	0.13
	24 o.c.	0.09

Table 8. Framing Fractions
Source: Energy Gauge Framing Fractions Help Menu

Planned Updates

Version 1.8 of Energy Gauge was released in June 2006. Currently, there are no updates under development or planned. Any future major software updates or new releases will be issued in conjunction with code changes by the Florida Department of Consumer Affairs.

Conclusions on EnergyGauge, USA

Overall, Energy Gauge is one of the most robust of the simulation tools frequently used for code compliance, since it uses the DoE 2 simulation tool as its engine. It is geared toward the Florida market but also addresses the IECC.

The materials library in Energy Gauge is limited to one framing option for CFS, but if using this option, the user has an unlimited number of configurations that can be obtained based upon the user defined R-Values and framing factors. At this time, the materials library neglects CFS member sizing for all framing options.

The software uses the parallel path calculation method. This method overestimates the performance of metal assemblies.

Overall Discussion on Simulation Tools

A summary of the key issues resulting from this assessment is shown in Table 9.

	REM Design	REScheck	Energy 10	EnergyGauge
CFS in libraries?				
Walls	Yes, but very limited.	Yes	Yes	Yes
Floors	None	Yes	Yes	Yes
Roofs (Ceiling joists)	None	Yes	Yes	Yes
Roofs (Trusses)	None	Yes	None	Yes
Can libraries be modified?	Yes	Yes	Yes	Yes
Codes or Standards and Covered	ASHRAE 90.2; MEC- 1992, 1993, 1995; Southern Nevada, New York State; IECC- 1998, 2000, 2001, 2003, 2004, 2006;	MEC- 1992, 1993, 1995; IECC- 1998, 2000, 2003, 2006; IRC- 2006; State codes – AK, GA, MA, MN, NH, NJ, NY, VT, WS, & Pima County, AZ	ASHRAE 90.1-2004	IECC- 1998, 2000, 2003, 2004, and 2006; Florida Building Code
UA Approach	Yes	Yes	Yes	Yes
Reference-Home Based Approach	Yes	No	No	Yes
Calculation Method	Parallel path method with two paths. IECC factors applied to cavity insulation path	Parallel path method with a single path modified using 2003 IECC correction factors	Modified Zone Method	Parallel path method (without modifications)

Table 9. Summary of key issues

In general, there is a lack of consistency related to how each of the software programs calculates the thermal resistance or conductance of CFS members. Energy 10 uses an approach that appears to match the modified zone method recognized by ASHRAE and ORNL as the most accurate for CFS. This method separates the assembly into the framed and non-framed sections and performs parallel path calculations on each section. A modification is made to the effective

width of the CFS member's flange to take into account the impact of steel on the effectiveness of the adjacent cavity insulation.

REM Design, REScheck and EnergyGauge all use variations of the parallel path calculation method and apply framing factors to arrive at an Effective R- or U-Value. REM Design and REScheck apply the parallel path method in accordance with the 2003 IECC, except that they interpret it differently. REM Design uses a dual path method with the cavity path modified using the 2003 IECC correction factors, whereas REScheck uses one path through the cavity with the insulation factored according to the IECC. Energy Gauge, on the other hand, uses a pure parallel path method with two uncorrected paths (through the framing and through the cavity) that are combined.

Generally, the parallel path method overestimates the effective R-Value of a CFS assembly, whereas, the zone method underestimates it and the modified zone method brings it more in line with test and finite element analysis results. However, it is difficult to tell definitively whether the methods that are used for some of the simulation tools result in an overestimate or underestimate of the thermal performance of a steel building. This is mainly because several of the tools use a method described in the 2003 IECC that appears to be somewhat of a hybrid between the parallel path and modified zone methods.

In addition, it is difficult to compare calculated U values without a baseline against which to base the comparison. Although test results are available for a wide variety of wall and floor assemblies, they are for the most part clear wall assemblies. The framing factor that is used must be accounted for in order to compare tested assemblies with the R- or U-Values in the library files or those calculated by the software programs.

One approach to assessing how the models compare to reality is to assume the modified zone method is the most accurate method. In this scenario, Energy 10 would appear to address steel in the most accurate manner of the models assessed. At the other extreme, we are certain that the pure parallel path method used in Energy Gauge would tend to overestimate the effective R-Value of a CFS assembly.

With REM Design and REScheck, the comparison is more difficult. Generally, the parallel path method overestimates the performance of steel. However, each of these simulation tools uses a calculation method that combines the parallel path and modified zone methods by using correction factors from the 2003 IECC. From the simulations we conducted, each of these appears to overestimate the effectiveness of steel.

Understanding the methodology behind the CFS calculations of U- or R-Values is critical when trying to use these programs. Otherwise, if a user selects defaults or library files as is, they will not likely end up with an accurate model of the

building. With programs like REM Design, the user can follow a “trial and error” method to obtain specific U-Values or R-Values, but a modified zone method calculation would first need to be performed to arrive at the correct target values.

Without accurate CFS library entries or calculation methods for Effective R- or U-Values, the user could end up with a building that the software would indicate is code compliant, even though it may not in fact comply with the intent of the code. This may partly explain the many anecdotes we hear about REScheck, REM Design, or other simulation tools passing a building without the continuous insulation on walls required by the prescriptive methods in the IECC and IRC. This also poses a dilemma for the steel industry – whether to propose changes to the tools knowing that some buildings would no longer be compliant if a modified zone method is adopted.

Appendix- Calculation methods and other terms

Calculation Methods Recognized by ASHRAE

There are three methods described in the ASHRAE Handbook of Fundamentals that have been commonly used to determine the effective or component U-Values for a framed building assembly – the parallel path method, the zone method (sometimes called the ASHRAE zone method), and the modified zone method. Each of these methods can technically be termed a parallel-path calculation. The difference between the methods is how (or if) a correction is made to address the thermal bridge contributed by the steel members.

Parallel Path Method - In the Parallel Path Method, no correction is made for the influence of the steel members. Thus, the R-Values of the components in the assembly are summed for two paths – one through the cavity center and one through the steel member. The user assumes that the thermal bridge zone equals the width of the stud flange. The surface area of the steel framed sections and the cavity sections are then multiplied by the inverse of the R-Values to arrive at a composite U-Value. The parallel path calculation tends to overestimate the R-Value for cold-formed steel, or underestimate the U-Values.

The ASHRAE Handbook of Fundamentals indicates that the parallel path method should not be used for metal assemblies. It is more appropriate for assemblies like wood framed walls where the studs have little influence over the effectiveness of adjacent cavity insulation.

Zone Method - The zone method can be used for a variety of material types and is similar to the parallel path method except that the flange width is assumed to be greater than its actual dimension. In the Zone Method, the CFS flange width is increased by two times the total thickness of all finish material layers on the thicker side of the CFS member. This has the effect of increasing the amount of area that is assumed to be influenced by the steel member. As in the parallel path method, the R-Values are weighted based on the percentage of non-framed wall area to give an effective R-Value for the component. The zone method tends to underestimate the effective R-Value of a steel assembly, or overestimate the U-Value.

Modified Zone Method - The Modified Zone Method was developed by Oak Ridge National Laboratory as part of a test program funded by AISI in the early 1990s. It is described in the 1995 AISI Thermal Design Guide and in the ASHRAE Handbook of Fundamentals. With this method, the flange width is widened by increasing its dimension by a term called “zf” that is multiplied by the total thickness of all finish material layers on the thicker side. The term “zf” is defined as a ratio between thermal resistivity of finish material and cavity insulation. Thus, the modified zone method is similar to the zone method in that

it widens the assumed width of the flange, but the width ends up smaller than in the zone method.

The modified zone method calculation again breaks the assembly into two sections (framed and non-framed) and performs the parallel path calculations on each section. The modified zone method is believed to yield the most accurate results of the calculation methods based on comparison to test results and finite element analysis conducted by ORNL. It is the method recommended in the ASHRAE Handbook of Fundamentals for metal framing. It is sometimes called the ORNL method, although the modified zone method is the generally recognized name.

2003 IECC Correction Method - Further confusing the issues over calculation methods, the 2003 IECC requires users of the code to apply a parallel path approach to CFS assemblies and to apply specific path correction factors. The code is not clear as to how these factors are to be applied, or how they relate to the modified zone or zone methods. The IECC method appears to be an attempt to bring the treatment of CFS into agreement with thermal test results and studies conducted by ORNL and others. It may correlate well with the modified zone method but without a comprehensive comparison between the two methods this is only an assumption on our part. Access to the code changes that resulted in the 2003 code edition could shed further light on the rationale behind the method. In any case, it is clear by examining the different simulation tools that there is not universal agreement on how to apply the 2003 IECC text.

Framing Factor - This is the area that is taken up by the framing, including studs, track, headers, jambs, and all other framing. It is typically expressed as a percent or a decimal of the framing relative to overall wall (or floor or ceiling) area. Typical framing factors run from about 15% to as high as 25%. The term framing fraction is also frequently used in place of framing factor.

Effective R-Value and U-Values - The effective R-Value is the value of an entire assembly as opposed to just the R-Value of the cavity insulation. This is typically converted to a UA for the assembly by first inverting the R-Value and multiplying it by the surface area (A) of the component. In simple terms, a U-Value is the inverse of the R-Value.

The term “effective” is often used interchangeably with the term “composite” for both the U- and R-Values. In either case, it is a measure of the overall thermal performance of the wall, floor, or ceiling, taking into account all components of the assembly. In addition, the U-Value is sometimes called the U Factor.