SPRAY POLYURETHANE FOAM AND THE CALIFORNIA TITLE 24 2016 REQUIREMENT FOR HIGH PERFORMANCE ATTICS

A Focus on Energy Modeling for Spray Polyurethane Foam Unvented Attics in Title 24-Approved Compliance Software Programs

ConSol

American Chemistry Council | Spray Foam Coalition

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The Spray Foam Coalition (SFC) champions the use of spray polyurethane foam in U.S. building and construction applications and promotes its economic, environmental and societal benefits while supporting the safe manufacture, transport, and application of spray polyurethane foam. SFC consists of manufacturers of spray polyurethane foam systems as well as suppliers of raw materials and machinery used to apply the foam.

ConSol is a California corporation that provides broad experience with residential and nonresidential energy efficiency, retrofit, and green program design and management; building audits and training. ConSol also offers leading-edge research and energy consulting in systems and technologies to improve sustainability of new and existing residential and commercial buildings.

Executive Summary:

The California Energy Commission's (CEC) 2016 Title 24 requirements call for High Performance Attics (HPAs) in new single-family residential buildings. Builders can follow one of two prescriptive paths to construct an HPA, or they can use the performance method to get compliance credit for alternative designs.

A proven alternative design for HPAs is the application of spray polyurethane foam (SPF) insulation on the underside of the roof deck to create an unvented attic (UVA). SPF UVA designs have a long history of use and have become even more popular since being added to the International Residential Code in 2009.

The user interfaces for the two most common energy simulation tools used to assess compliance credit under the Title 24 performance path (EnergyPro v6.7.0.3 and CBECC-Res 2013-v4 (744)) are currently not configured to easily model UVA performance. This technical brief provides guidance on simulating UVAs using these energy modeling tools.

For a typical home in three different CEC climate zones, the modeling runs demonstrate that a UVA with R-28 SPF slightly outperforms the 2016 Title 24 prescriptive designs. Use of R-38 SPF to create a UVA is shown to significantly outperform the prescriptive HPA attic designs when more reliable modeling is applied.

New Title 24 Requirements for 2016:

The CEC has developed a new set of energy efficiency regulations for single-family residential buildings, which will go into effect on January 1, 2017. The key changes include: reduced air leakage and R-Value for ducts located in the attic; tankless water heating; LED lighting; high performance walls (HPWs); and high performance attics (HPAs). Many builders already use tankless water heating and LED lighting—or they have been prepared for the transition by prior changes to Title 24 such as the "tankless ready" provisions in the 2013 code—and the changes to duct performance are minor variations on an existing theme. However, the new HPW and HPA requirements mark a significant change for most builders—and they present a new set of challenges for those modeling with performance-based code compliance software tools.

A. Introduction

A popular design concept for High Performance Attics (HPAs) in residential construction incorporates spray polyurethane foam (SPF) on the underside of the roof deck to create an unvented attic (UVA) assembly. The SPF UVA was first used in the 1970s and has grown in popularity since it was added to the International Code Council's Residential Building Code in 2009. The SPF UVA has also been carefully studied for thermal and moisture performance in many different climates.

The widespread use and demonstrated performance of SPF UVAs make them a top choice for meeting the California Energy Commission (CEC) 2016 Title 24 requirements. In order to get full compliance credit for the SPF UVA design, it is important to model the attic correctly when using one of the CEC-approved Title 24 compliance software programs. This technical brief outlines the new 2016 code requirements and provides guidance on modeling SPF UVAs in the two Title 24 compliance software packages widely used in the industry today: EnergyPro and California Building Energy Code Compliance Residential (CBECC-Res) software.

B. Prescriptive Requirements for HPAs

The CEC has promoted the use of performance-based compliance with the Title 24 energy code. As an example, the 2016 Title 24 Standards do not provide a specific prescriptive wall package, but instead point to a "prescriptive" performance value of U=.051, which sets the energy budget in the software. The CEC provides ideas and alternatives for wall assemblies that can meet or exceed U=.051, but does not hold up any one design as the "prescriptive" option.

In contrast, the CEC does provide two prescriptive options for meeting the HPA requirement. Both of these designs retain the passive attic ventilation strategies and ceiling insulation levels from past code cycles—and then add a layer of insulation to the roof deck for homes built in most of California's sixteen CEC Climate Zones (CZ). In addition to the two basic prescriptive options, there is also a slight difference in the prescriptive R-value of the roof deck insulation for each prescriptive approach. If the roofing material is raised on battens, creating an air space between roof tiles and the roof deck, the required roof deck R-value is lowered to account for the added insulation value provided by the air space.

The two prescriptive options are:

1. R-30 or R-38 at the ceiling (depending on CZ) combined with R-13 or R-18 insulation below the roof deck (depending on the presence of air space between the roof deck and tile).
2. R-30 or R-38 at the ceiling (depending on CZ) combined with R-6 or R-8 rigid foam above the roof deck (depending on air space).

Although these two approaches to building ventilated HPAs are based on sound assumptions, neither of the prescriptive options have been widely deployed or studied. In contrast, SPF UVAs are a time-tested and proven technology for dramatically reducing air infiltration and effectively moderating attic temperatures.

C. SPF UVA as a Performance Alternative

In addition to the prescriptive options described above, builders can choose any number of different options for performance-based compliance—provided that the option meets other building code requirements. The application of SPF below the roof deck in a UVA configuration is a widely adopted approach to HPA design. This HPA design seals the attic from air infiltration, effectively bringing the space into the conditioned building envelope, which provides energy savings beyond the performance gains from only insulating the roof deck.

The R-value of the below-deck insulation in an SPF UVA is greater than that used for either prescriptive option because no insulation is used at the ceiling. This creates a robust thermal barrier at the building envelope. **Figure 1** shows an example of a conventionally-insulated vented attic containing an HVAC system. **Figure 2** illustrates the performance features of an SPF UVA assembly. **Figure 3** provides an image of an actual SPF UVA assembly.

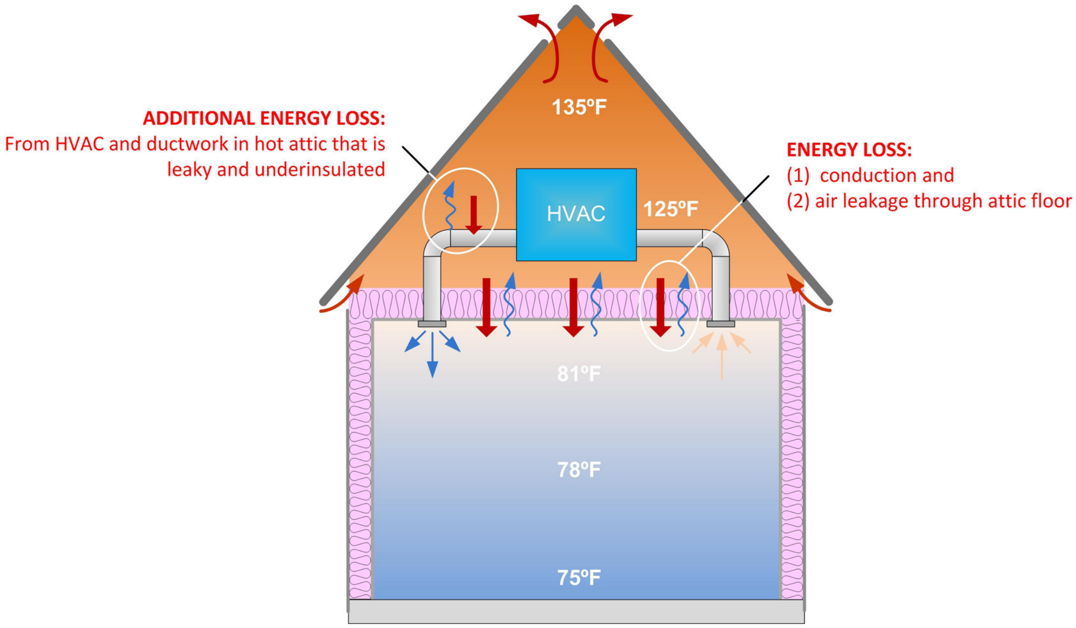


Figure 1 – Conventionally-insulated ventilated attic
Courtesy of Duncan Engineering, Inc.

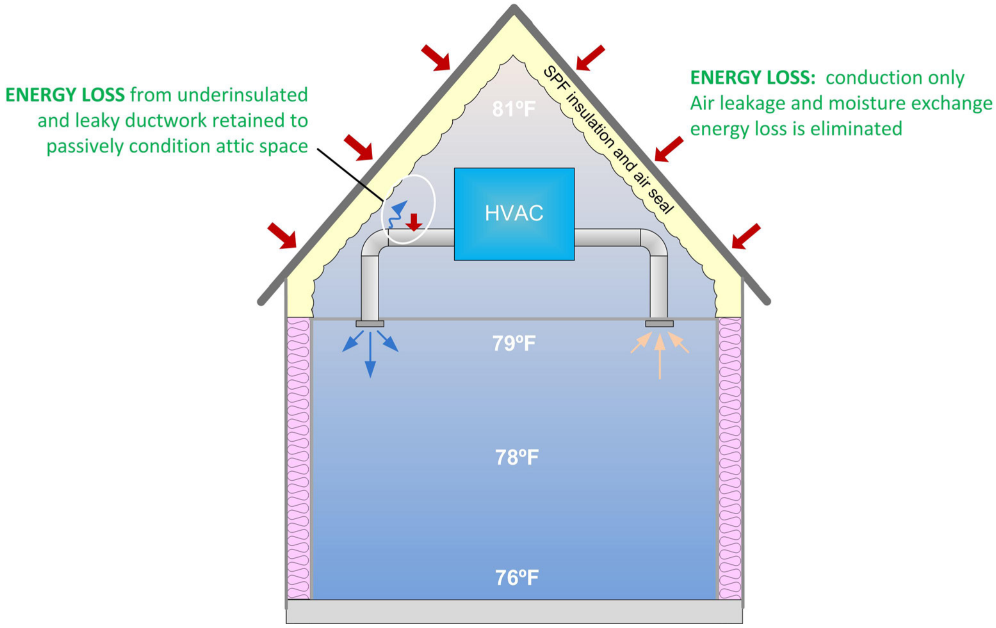


Figure 2 - Unvented attic assembly using SPF insulation
Courtesy of Duncan Engineering, Inc.

Figure 3 - Unvented attic assembly using SPF insulation
(Note: rafters covered to provide layer of continuous insulation)
Courtesy of Spray Polyurethane Foam Alliance

D. Changes to Minimum R-Value Requirements

The 2013 Title 24 Standards include a *mandatory minimum* attic insulation R-value of 30, regardless of Climate Zone and regardless of the prescriptive value (which is either R-30 or R-38). This minimum R-value requirement applies to insulation located at the ceiling or at the roof deck (or the sum of ceiling plus roof deck R-values).

Insulation placed at the roof deck modulates both the temperature of the attic and the HVAC system ducts located in the attic space. Placing insulation at the ceiling plane only creates a thermal barrier for the occupied space below. Therefore, insulation at the roof deck can be far more effective in terms of overall energy efficiency than insulation placed at the ceiling.

In recognition of that fact that R-22 SPF located at the roof deck is an effective method of insulating the attic, the 2016 Title 24 Standards have reduced the mandatory minimum R-value for attic insulation to R-22. Energy modeling conducted for this report demonstrates that the performance of an R-22 SFP UVA as slightly lower than the prescriptive approach for the specific home design modeled. In this modeling scenario, an R-28 SPF UVA appears to offer slightly better energy performance than the prescriptive design, which combines R-38 at the ceiling plus R-13 at the roof deck for a total of R-51.

Results will vary between different Climate Zones and different home designs. Energy compliance software must be used to determine whether an R-22, R-28, or other R-value SPF application below deck will meet the project-specific objectives for cost, comfort, usable attic space, wildfire safety, equipment trade-offs, and other considerations.

E. Modeling SPF UVAs

The increasing focus on performance-based code compliance in California makes it important to understand how each available Title 24 compliance software package works, and how to input data to get reliable and accurate modeling results.

Each software product has a different User Interface (UI), which is where the building equipment and assemblies are entered and defined. Since the compliance engine is the same for all approved software products, users should (in theory) get the same results from CBECC-Res, EnergyPro[1], or Right-Energy Title 24—the three software packages approved by the CEC for Title 24 compliance in residential buildings.

1 EnergyPro is a third party software owned by EnergySoft. EnergySoft is responsible for the EnergyPro user interface. Any comments or issues with EnergyPro should be directed to EnergySoft.

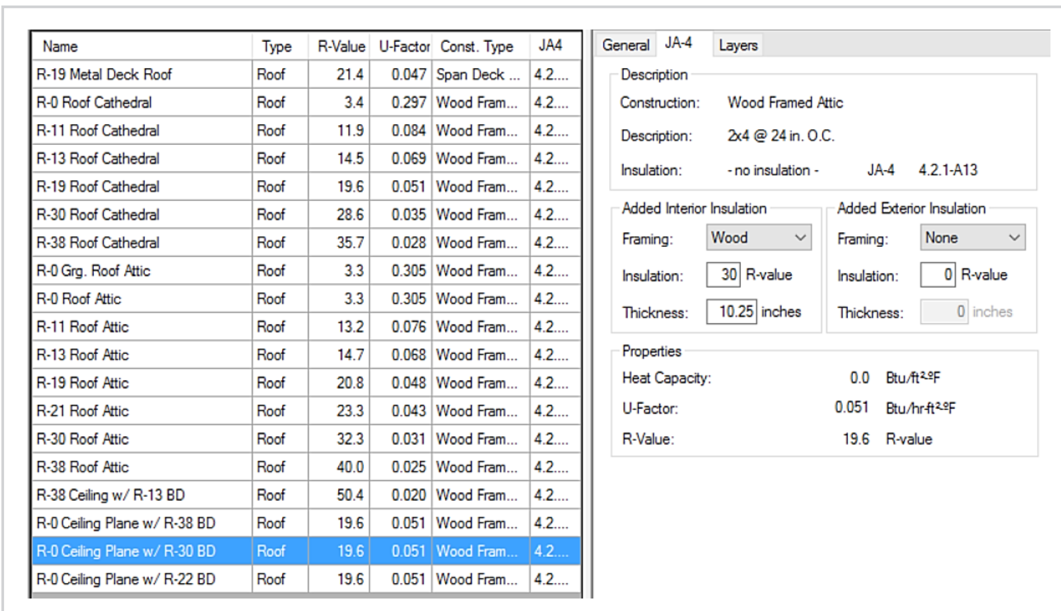
CEC Software Approval Process:

As part of the 2013 Title 24 update, the CEC made a major change to the way compliance software is engineered and approved for use by the State. Under this new approach, the CEC and their consultants began to create the "compliance engine" in-house. The compliance engine—which includes all the algorithms used to calculate energy loads—resides within the free, public domain software published by the CEC, which is known as CBECC-Res. It is also available to the public through two software vendors, EnergySoft, which publishes the software EnergyPro, and WrightSoft's Right-Energy Title 24. This approach to software approval allows skilled users to test the validity of modeling results produced by one software product by recreating the design in a different product.

However, the UIs for each product vary considerably, which can result in confusion and inconsistent approaches to modeling building assemblies, in particular SPF UVAs. As a result, it is of particular importance that users fully understand the approach to modeling SPF UVAs in the specific program of their choice. This report provides guidance for modeling SPF UVA designs with EnergyPro and CBECC-Res.

1. EnergyPro (v6.7.0.3)

EnergyPro requires the user to build the roof deck assembly within the JA-4[2] dialogue window. The software allows the user to specify the location and amount of both below-roof deck and above-roof deck insulation within the same interface. A typical SPF UVA assembly would be described as "R-0 Ceiling Plane w/ R-30 BD [below deck]," as shown on the right hand side of **Figure 4**.



Name	Type	R-Value	U-Factor	Const. Type	JA4
R-19 Metal Deck Roof	Roof	21.4	0.047	Span Deck ...	4.2....
R-0 Roof Cathedral	Roof	3.4	0.297	Wood Fram...	4.2....
R-11 Roof Cathedral	Roof	11.9	0.084	Wood Fram...	4.2....
R-13 Roof Cathedral	Roof	14.5	0.069	Wood Fram...	4.2....
R-19 Roof Cathedral	Roof	19.6	0.051	Wood Fram...	4.2....
R-30 Roof Cathedral	Roof	28.6	0.035	Wood Fram...	4.2....
R-38 Roof Cathedral	Roof	35.7	0.028	Wood Fram...	4.2....
R-0 Grg. Roof Attic	Roof	3.3	0.305	Wood Fram...	4.2....
R-0 Roof Attic	Roof	3.3	0.305	Wood Fram...	4.2....
R-11 Roof Attic	Roof	13.2	0.076	Wood Fram...	4.2....
R-13 Roof Attic	Roof	14.7	0.068	Wood Fram...	4.2....
R-19 Roof Attic	Roof	20.8	0.048	Wood Fram...	4.2....
R-21 Roof Attic	Roof	23.3	0.043	Wood Fram...	4.2....
R-30 Roof Attic	Roof	32.3	0.031	Wood Fram...	4.2....
R-38 Roof Attic	Roof	40.0	0.025	Wood Fram...	4.2....
R-38 Ceiling w/ R-13 BD	Roof	50.4	0.020	Wood Fram...	4.2....
R-0 Ceiling Plane w/ R-38 BD	Roof	19.6	0.051	Wood Fram...	4.2....
R-0 Ceiling Plane w/ R-30 BD	Roof	19.6	0.051	Wood Fram...	4.2....
R-0 Ceiling Plane w/ R-22 BD	Roof	19.6	0.051	Wood Fram...	4.2....

Figure 4 - JA-4 Dialogue Box and Drop-down Selection Menu (EnergyPro)

In order to create the assembly in the drop down menu, the user can first use the "R-0 Attic" from the materials library, and then select framing and insulation R-value in the "Added Interior Insulation" dialogue box, as shown on the right hand side of **Figure 4**. It is not necessary to callout the thickness of the insulation because the R-value supersedes that input. Furthermore, assembly R-values shown on the left-hand-side list are not accurate—note that all three UVA assemblies—R-22, R-30, and R-38—are all shown as having an R-19.6 assembly value. This does not affect the calculated energy performance of each design, as shown in **Figure 11**. Also, it is important to note that the software does not distinguish between insulation type (fiberglass, cellulose, open-cell SPF or closed-cell SPF)—only the R-value is used for the calculation.

2 JA-4 refers to Chapter 4 of the Joint Appendices to the (residential and non-residential) Title 24 Compliance Manual. The assumptions about each roof assembly (such as overall U-factor) are housed in the Joint Appendices.

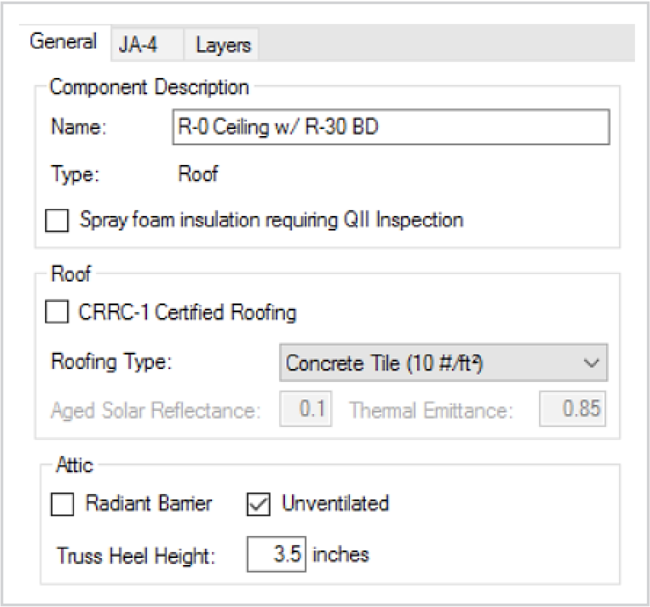


Figure 5 - General Attic/Roof Assembly Information incl. "Unventilated" Selection (EnergyPro)

As shown under the "General" tab (see **Figure 5**), there is a note that reads "Spray foam insulation requiring QII inspection". The radio button preceding this note should be checked when spray foam is used to trigger the correct HERS inspection forms. However, as discussed previously, this selection should not affect the way that the software calculates building energy use and compliance margin. To complete the SPF UVA model in EnergyPro, the user selects the "Unventilated" radio button found in the "General" tab, where the roof and attic assembly is originally created, as shown in **Figure 5**.

2. CBECC-Res (2013-v4 (744))

In contrast to EnergyPro, CBECC-Res requires the user to build the roof deck assembly in a different dialogue box from the attic ceiling. The "Construction Data" dialogue box pictured in **Figure 6** allows the user to name the assembly, and then define the parameters for the roof deck. Within the "Cavity/Frame" drop-down menu the user selects the R-value for the roof deck SPF insulation that will be used.

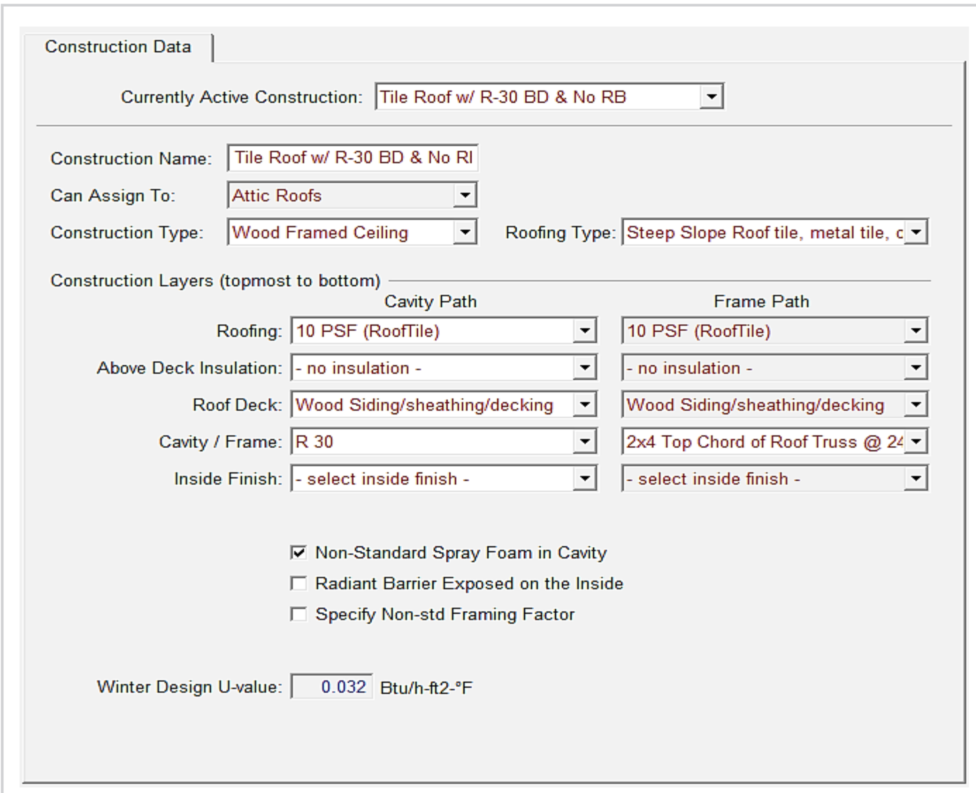


Figure 6 - Construction Data for Roof Deck Assembly (CBECC-Res)

As shown in **Figure 6**, checking the radio button for "Non-Standard Spray Foam in Cavity" when using SPF triggers the HERS inspection forms. However, like EnergyPro, the type of insulation selected does not influence the modeling results.

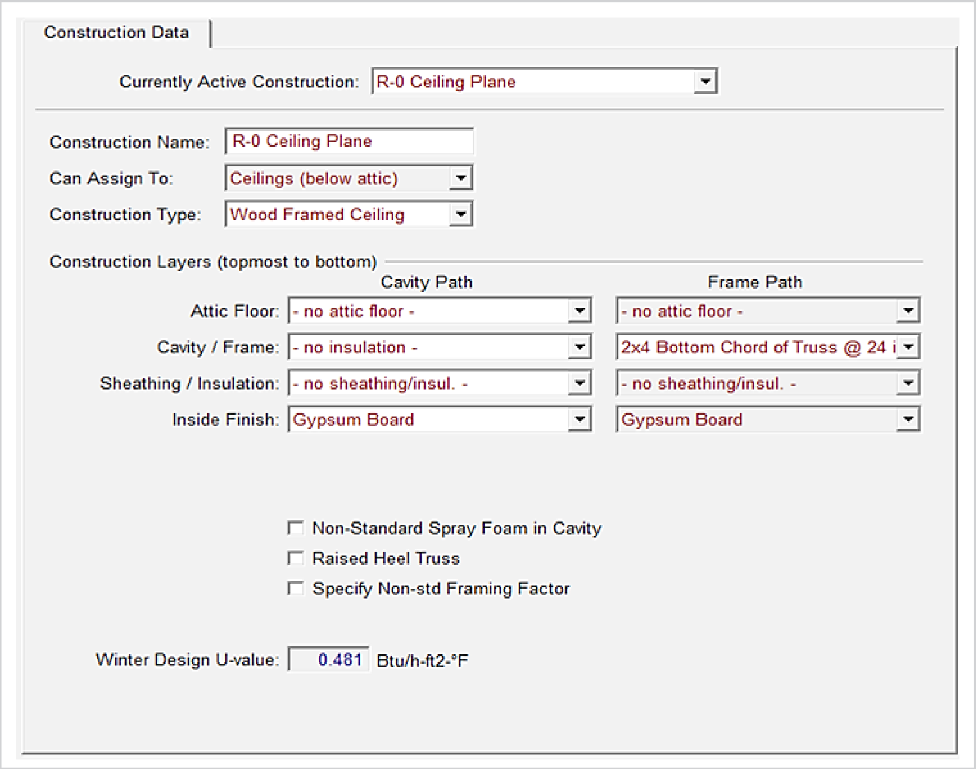


Figure 7 - Defining the R-0 Assembly for the Ceiling (CBECC-Res)

Unlike EnergyPro, which requires the user to describe the entire attic assembly within one interface, CBECC-Res requires the user to create an additional assembly to reflect the elimination of the insulation at the ceiling plane, as shown in **Figure 7**.

Lastly, the user selects “Unventilated” from the “Attic Conditioning” drop-down menu under the “Attic Data” tab in CBECC-Res, as shown in **Figure 8**.

Figure 8 - Attic Data and Attic Conditioning (CBECC-Res)

F. Common Errors in Modeling SPF UVAs

As described above, the UIs for CBECC-Res and EnergyPro take different approaches to defining the attic assembly. CBECC-Res requires the user to define the roof deck and ceiling assemblies within two different dialogue boxes. This can reduce the likelihood of error as it is clear to the user which part of the attic is being described. In contrast, EnergyPro treats the entire attic (including the ceiling plane and roof deck) as an "assembly," which may cause some users to incorrectly account for insulation twice.

One common mistake in EnergyPro is for users to start with an attic assembly with insulation already called out, such as an "R-38 Roof Attic," which is EnergyPro's way of describing an attic with R-38 at the ceiling plane and no roof deck insulation. If the user attempts to redefine the R-38 Roof Attic to move the insulation from the ceiling to the roof deck, the modeling software will assume that the attic has R-38 at the roof deck and at the ceiling (see **Figure 9**). Removing the R-38 at the ceiling requires additional steps and can easily lead to inaccurate results. One option to model a UVA with only below deck insulation is to select an "R-0 Roof Attic" from the materials library in EnergyPro, and then modify the roof deck to include the required insulation value. For increased accuracy, the user can rename the construction design to describe it as a "UVA Assembly."

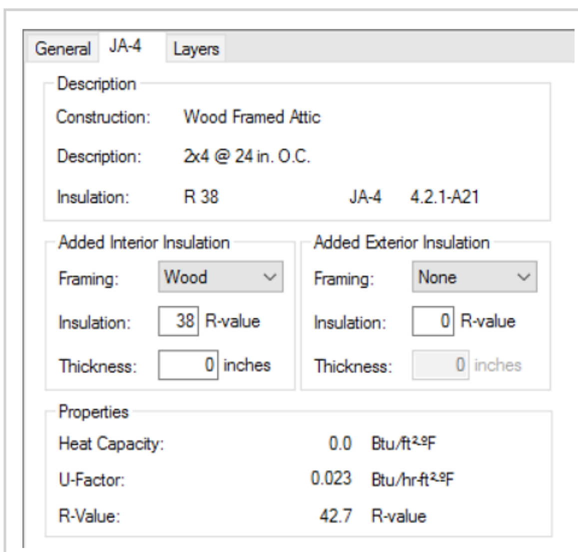


Figure 9 - Defining the Attic Assembly (EnergyPro Modeling Error)

Another common mistake within EnergyPro is for the user to describe the insulated roof deck as a "Rafter/Cathedral Ceiling," as this appears to many users to be the closest way to describe an unvented attic with no insulation at the roof deck (see **Figure 10**). Although similar in some ways, unvented attics have different characteristics from cathedral ceilings and should be modeled accordingly. It is less likely that a modeler will make a similar mistake using CBECC-Res due to the different UIs and the process for creating a UVA within the software program.

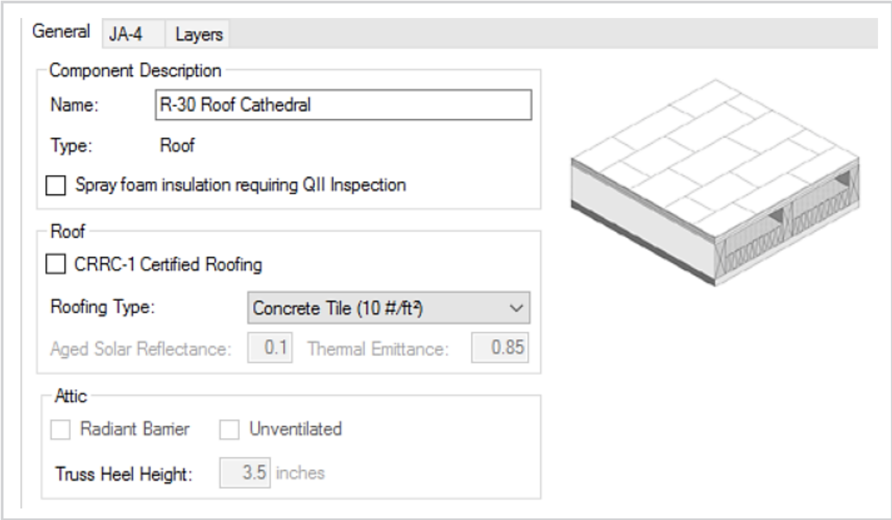


Figure 10 - Describing UVA as Cathedral Ceiling (Energy Pro Modeling Error)

Lastly, due in part to the low performance credit that earlier versions of 2013 Title 24 compliance software provided when modeling UVAs, many energy modelers selected "Ducts in Conditioned Space," given that a UVA can be considered semi-conditioned. However, software engineers for CBECC-Res and EnergyPro have indicated that the "Ducts in Conditioned Space" credit is meant to refer to directly conditioned space and that selecting this option is not the correct way to model an indirectly conditioned UVA. Software updates have provided far greater credit for UVAs, reducing the compliance margin given from selecting "Ducts in Conditioned Space." As demonstrated below, adding that option to a UVA assembly does very little to improve compliance margins. As such, energy modelers should select "Ducts in Attic" for UVA designs.

G. Comparison of UVA Energy Performance to Prescriptive Alternatives

The application of more reliable modeling procedures shows that EnergyPro and CBECC-Res both provide the same compliance margins for SPF UVAs. Since compliance margins are a relative measure of building efficiency, it is important that the user be aware of the relative performance of different assemblies as a means of validating modeling results. The bold figures shown as "Improvement vs. Base Case" near the bottom of **Figure 11** represent this relative performance metric.

As shown in **Figure 11**[3], the baseline design "A" is very close to compliance with the 2013 Title 24 Standards in Climate Zone 12.[4] This equivalence is expected because it represents the prescriptive requirements for 2013: R-30 or R-38 at the ceiling in a passively ventilated attic with a radiant barrier at the roof deck.

		Base Case 2013 Prescriptive	2016 Prescriptive Attic "B"	2016 Performance w/ R-22 SPF	2016 Performance w/ R-28 SPF	2016 Performance w/ R-38 SPF	2016 Performance w/ R-38 SPF*	2016 Performance w/ R-38 SPF**
	SCENARIO:	A	B	C	D	E	F	G
Attic and Duct Configuration:	**Attic Ventilation:**	Vented	**Vented**	**Sealed UVA**	**Sealed UVA**	**Sealed UVA**	Vented*	Sealed UVA
	Roof Deck Insulation:	Radiant Barrier	**R-13**	**R-22**	**R-28**	**R-38**	R-38	R-38
	Ceiling Insulation:	R-38	**R-38**	**None**	**None**	**None**	None	None
	Duct Location:	Attic	**Attic**	**Attic**	**Attic**	**Attic**	Attic	Cond. Space**
Percent better than code in select CA Climate Zones:	**4 (San Jose)**	19.2%	**25.1%**	**22.8%**	**25.5%**	**29.3%**	24.4%	30.1%
	10 (Riverside)	7.5%	**20.2%**	**16.0%**	**20.8%**	**25.7%**	21.7%	28.1%
	12 (Sacramento)	4.8%	**17.0%**	**12.4%**	**17.7%**	**22.9%**	19.1%	24.7%
	Average	10.5%	**20.8%**	**17.1%**	**21.3%**	**26.0%**	21.7%	27.6%
	Improvement vs. Base Case	N/A	**10.3%**	**6.6%**	**10.8%**	**15.5%**	11.2%	17.1%
			2016 Prescriptive	**SPF UVA: R-22**	**SPF UVA: R-28**	**SPF UVA: R-38**		

**Modeled as "Ventilated" (incorrect)* ***Modeled as having "Ducts Entirely in Conditioned Space" (incorrect)*

Figure 11 - Relative Compliance Margins for Baseline vs. Prescriptive and Performance 2016 Title 24 Compliant HPA Designs[5]

The 2016 prescriptive attic design (column "B") improves compliance by 10.3% on average across the three Climate Zones tested (as compared to the 2013 baseline). The R-22 SPF UVA falls short of the 2016 prescriptive approach, but design "C" outperforms a 2013 attic design with an average improvement of 6.6% above baseline. The R-28 SPF UVA (column "D") outperforms the 2016 prescriptive approach and significantly outperforms a 2013 attic design with an average improvement of 10.8% above baseline. The R-38 SPF UVA attic (column "E") achieves a relative compliance margin of 15.5% on average—significantly better performance than the prescriptive attic design.

3 Figure 11 represents energy modeling done with CBECC-Res 2013 code compliance software, using the CEC's prototypical 1-story 2100 square foot single-family home. The base case represents a prescriptive attic for a 2013 home, but not all features are modeled to match prescriptive requirements. All features aside from attic insulation, ventilation, and duct location were held constant to observe the impact of those three factors. Results may vary by Climate Zone, home size, number of stories, or other configuration details, but the relative performance of the different attic designs should roughly follow these examples. If your modeling results deviate substantially from these, please contact Garth Torvestad (gtorvestad@consol.ws) at ConSol for help troubleshooting.

4 In order to simplify and reduce margin of error in the modeling results, the modeled home in Figure 11 was designed to comply (margin of 0.5%) with 2013 code in CA Climate Zone 12, and then re-run in CZ 4 and CZ 10 with no changes. That 2013 baseline design was then modified with 2016 prescriptive and performance attic designs and re-run without any additional Climate Zone-specific changes that would be required to achieve smaller margins in CZ 4.

5 The four correctly-modeled, 2016-compliant prescriptive and performance attic designs are shown in columns B-E.

As reference only, columns "F" and "G" show the energy impact associated with two common errors—modeling a UVA as "ventilated" and modeling ducts located in a UVA as "Ducts in Conditioned Space." Although an SPF UVA is "semi-conditioned," selecting "Ducts in Conditioned Space" informs the software that the ductwork is located outside of the UVA in a dropped plenum. Since this approach to duct design would do very little to improve energy performance beyond what is already gained by creating an SPF UVA, it is no surprise that the software gives very little credit to this approach (compliance margins increased by only 1.6% on average). In other words, the better the attic performance, the less benefit there is from moving ducts into conditioned space via dropped plenums.

With the understanding that builders may have difficulty altering existing floor plans to accommodate dropped plenums in order to move ducts into the conditioned space, there is a strong argument that designs "D" and "E"—typical SPF UVAs—offer compelling options for improving compliance margin without eliminating living space, dropping ceiling heights, or otherwise disrupting existing home designs.

H. Other Resources

This guidance was produced with the technical assistance of ConSol and support from the ACC Center for the Polyurethane Industry's Spray Foam Coalition. Additional technical assistance is available to builders and energy efficiency providers to create a greater understanding of High Performance Attics (HPAs) and High Performance Walls (HPWs) in advance of, and during the implementation of, the 2016 Title 24 Standards. Through a grant from the CEC, the California Homebuilding Foundation and ConSol, along with industry partners, have created free resources for California builders and energy efficiency professionals. Under the CEC's Electric Program Investment Charge (EPIC) Workforce Instruction for Standards and Efficiency (WISE), the available resources include:

- Energy modeling assistance for HPAs and HPWs
- Evaluation of trade-offs and design optimization to transition to HPA and HPW designs
- Value engineering meetings to coordinate subcontractors and/or builder divisions with the transition to HPA and HPW
- Plan review
- Seminars and product forums for HPA and HPW designs
- Field product demonstration and installer trainings

Contact Information:

For more information on these EPIC WISE resources, including energy modeling assistance for HPAs and HPWs, contact Garth Torvestad at gtorvestad@consol.ws, (209) 473-5028.

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