# Measure Information Template -

# Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs (and other cool roof updates)

*2008 California Building Energy Efficiency Standards*

**Cool Metal Roofing Coalition**

**July 10, 2006**

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# Overview

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| Description | A PIER Report, *Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24*, dated May 17, 2006 [Ref. 1] was presented at the May 18, 2006 Staff Workshop by Dr. Hashem Akbari. This PIER Report actually proposes new cool roof requirements for both residential and nonresidential buildings (Attachment 2 of Ref. 1). Therefore, this template also addresses both residential and nonresidential buildings.<br><br>The mandate of the Energy Action Plan II [Ref. 2] is for the adoption of cost effective energy efficient measures. The Pier Report [Ref. 1] provides a summary of the cost effective analysis that was carried out for residential roofs (both low and steep slope). A second Pier Report [Ref. 3] addressed steep sloped nonresidential roofs. The cost effectiveness study presented in P G & E's original proposal [Ref. 4] that led to the adoption of the low slope nonresidential prescriptive requirement will also be revisited since no new cost effective study has been presented.<br><br>The Cool Metal Roofing Coalition agrees that the inclusion of solar reflectance and thermal emittance requirements for residential roofs is justified in Title 24. However, we do not think the PIER report proposal is equitable with regard to all the factors that must be considered in the residential roof market. This Measure Information Template provides an alternate recommendation with regard to residential buildings, and seeks to correct inaccurate cost assumptions used in the cost effective study for nonresidential buildings.<br><br>The Cool Metal Roofing Coalition supports the use of aged total solar reflectance (TSR) and thermal emittance (TE) data for the prescriptive criteria for both residential and nonresidential buildings. The Coalition feels that one standard prescriptive TSR and TE value should be chosen for all types of cool roofing products used in the residential market. Therefore, our proposal is to use a minimum requirement of 0.25 TSR for all roofing products. Rationale for this, based on market considerations and the cost effectiveness study presented in the PIER report as well as other methodologies will be provided. |
| Type of Change | The proposed change would introduce a prescriptive requirement for cool roofing in residential steep slope applications. Additional updates for low slope commercial roofing are also proposed based on three-year aged values instead of initial values of solar reflectance and thermal emittance, and revisiting the cost effective study used in 2005. It would not change the way building envelope or whole building performance tradeoff calculations are made, however it would be based on using three-year aged values instead of initial values. Using data from the CRRC product directory would be part of the prescriptive requirement. |
| Energy Benefits | Reflective residential roofing can reduce cooling energy consumption by 18-26% compared to dark asphalt shingle roofing. In addition, cool roofs have been shown to reduce peak demand by 28-35% [Ref. 5]. The higher energy savings are |

realized with very light colors. New pigment technology in exterior durable paint systems permit darker colors to reflect more solar energy. Cool pigments in dark colors yield higher gains in solar reflectance than when used in lighter colors. Research conducted at ORNL and modeled using the AtticSim software have shown savings of 2-7 cents per square foot with cool roofs compared to black conventional roofing products. The magnitude depends on location, climate and energy costs.

A code change proposal based on a PIER project conducted by LBNL suggests a 0.25 TSR requirement for asphalt shingle and 0.40 TSR for all other types of roofing [Ref. 1]. In the residential roofing market, darker earth tone colors are popular with homeowners. The higher TSR requirement proposed would preclude the use of these colors, including reds, green, blue, brown, and gray hues. A TSR requirement of 0.40 would exclude 12 of the 18 Color Family groups in the CRRC Color Family Product Rating program. The six Color Families that would meet the 0.40 TSR prescriptive requirement are:

(1) Beige/Off White, (2) Tan, (3) White, (4) Bright White, (5) Pearlescent Silver, (6) Pearlescent Copper

LBNL, during questioning at the May19, 2006 Workshop, explained that they were able to achieve a 0.40 TSR for dark colors by using a bi-layer system that includes a white or reflective basecoat and an IR transparent topcoat. There are several issues with this technology for prepainted metal.

1. This bi-layer technique would add a coating layer, increasing costs. These increased costs have not been addressed in any analysis.
2. The black IR transparent top coat uses an organic black perylene pigment.
   a. Organic pigments are not the standard pigments used in long term (10 year plus) warranted products.
   b. There are no long-term South Florida weathering studies available with perylene blacks in PVDF or silicone-modified polyesters. South Florida weathering is the standard testing location. Accelerated tests such as UV cabinets and weatherometers and other weathering test sites are useful tools but are not the definitive test for weatherability.

According to calculations using the DOE Steep Slope Roof Energy Savings software, the difference in the cooling energy savings when comparing a roof with TSR=0.25 against a roof with TSR=0.40 amounts to less than $20 annually for cities in California. (2800 $ft^2$ roof, minimum IECC levels of insulation, and standard electricity costs) [Ref. 6].

The PIER project proposal [Ref. 1] excludes low-rise residential buildings in climate zones 1 through 9 and 12 for low-sloped roofs and climate zones 1 through 8 for steep-sloped roofs. The rationale is that all of the roofing products are not cost effective in these zones assuming a cost premium of $\$0.20/ft^2$.

As the Cool Metal Roofing Coalition has previously testified, the cost premium data that was used in the original study that justified the inclusion of cool roof

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| | prescriptive requirements for low-sloped nonresidential buildings contained inaccurate cost data with regard to painted metal roofing. Therefore it is logical and fair to revisit the original study [Ref. 4], using the same rationale as the new residential study to see if all of the roofing alternatives are cost effective in all of the climate zones. The flawed assumption that was used assumed that all roof products could achieve the proposed cool roof properties for less than $\$0.20/ft^2$. Metal roofing used in low-slope nonresidential applications will always be unpainted, so the cost premium to provide a cool roof is the added cost of painting the steel coils before the roofing products are formed. It is not just a matter of slightly more expensive pigments, but the cost of painting a product that is not currently painted. The added cost to use painted steel coils is approximately $\$0.50/ft^2$. Therefore, from Figure 6 in Reference 4, metal roofing would not be cost effective in zones 1 through 6, 11, 12, or 16. |
| Non-Energy Benefits | The suggested 0.25 TSR prescriptive requirement for cool roofing would help to mitigate the urban heat island in large populated areas. It would also permit a full palette of colors from which homeowners could choose roof aesthetics. Other non-energy benefits are described in the PIER report [Ref. 1]. |
| Environmental Impact | The measure does not have any adverse environmental impact. The special IR reflective pigments are incorporated into the paint systems used in the prepainted metal roofing industry, which are applied to the substrate in an environmentally clean continuous coil coating process in the factory. |
| Technology Measures | To achieve the higher TSR values in dark colors, special infrared reflective pigments must be used in the paint systems. There are an ample number of suppliers of these special pigments to the metal construction market. Exterior and accelerated laboratory testing have shown that these IR reflective pigments also enhance the durability, color retention and integrity of the paint films. By lowering surface temperature on the painted metal roofing product, less degradation of the paint system occurs over time. The paint systems carry performance warranties that exceed 30 years in many cases. The incremental cost for the IR reflective pigments is insignificant amounting to no more than 5 cents per square foot. (Note that this is the cost differential from a painted product that would be used in residential applications to a more reflective paint, as opposed to the cost premium in a nonresidential low-slope application where the cost differential is from an unpainted product to a painted product.) |
| Performance Verification | The EPA Energy Star program states that roofing products that meet or exceed the 0.25 TSR criteria can save up to 40% in cooling energy used in residential construction. Prepainted cool metal roofing was part of the PIER research conducted by LBNL. In all of the California climates, the cool prepainted metal roofing products displayed superior simulated annual energy savings, in every combination of insulation and radiant barrier usage. |

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| Cost Effectiveness | For residential applications, the measure is very cost effective. Improved solar reflectance, cooler surface temperatures and less heat gain into the attic can be achieved on prepainted metal roofing with practically no additional cost compared to conventional metal roofing products. The cost differential is the same for light or dark colors. The technology represents no significant change to the manufacturing process already used to produce prepainted metal roofing products for the residential market. |
| Analysis Tools | Actual measurements of cooling energy savings have been made on field installed roofs in California. This was part of the Cool Color Roofing research project funded in part by CEC. Similarly, field installations of cool prepainted metal roofing have been documented by the Florida Solar Energy Center. More recently, cool prepainted metal roofing was part of the PIER project conducted by LBNL. Simulations using various energy savings calculators can be used to model and predict cooling energy reduction in various climates of California. The DOE Steep Slope Roof Energy Savings calculator was used to compare cooling energy cost savings among roofing products with different TSR levels. |
| Relationship to Other Measures | This measure would have no impact on the way a cool roof is defined, or how tradeoff calculations would be made. |

# Methodology

The methodology for determining the proposed 0.25 TSR requirement for residential roofing was established by the EPA Energy Star program several years ago. That level of TSR allows for all types of steep slope roofing products to offer certain colors and variations to reduce cooling energy usage. The work conducted in the PIER project details methodology used and modeling to validate the annual energy savings and cost effectiveness of different types of roofing products. This proposal simply suggests that one standard level of a prescriptive TSR be used for all types of steep slope residential roofing products, based on the projected savings in annual energy usage and cost. AtticSim calculations in the DOE Steep Slope Roof Energy Savings Calculator can be used to compare the performance of roof products with various TSR values against a benchmark dark roof product.

Determining the incremental cost of the IR pigmented paint systems was based on conversations and evaluation of actual pricing information from suppliers of these pigments to the industrial coatings industry manufacturers.

For residential applications, the Life Cycle Cost Analysis was performed as part of the PIER study [Ref. 1]. This provided the total savings (cooling equipment savings plus 30-year net present value of energy savings) for all roofing products in all climate zones. This analysis should be reevaluated, using the same TSR of 0.25 for all roof products, however, intuitively; the painted metal roofs systems should be slightly more cost effective than the asphalt shingle roofs evaluated using a TSR of 0.25.

For nonresidential applications, the Life Cycle Cost Analysis of steep slope roofs is provided in the P G & E/LBNL study [Ref. 3]. No new Life Cycle Cost Analysis of low slope roofs was reported, so it is assumed that the previous study [Ref. 4] is still the basis for the cost effective analysis for this

segment of the nonresidential construction market. As previously stated, the cost premium assumed for metal roofing was not correct, and based on an actual differential cost of $\$0.50/ft^2$, the prescriptive cool roof requirements for low slope nonresidential applications, as introduced in the 2005 Title 24 are not cost effective in Climate Zones 1 through 6, 11, 12, or 16.

# Analysis and Results

Using the DOE Steep Slope Roof Energy Saving calculator, three cities were evaluated for annual cooling energy savings relative to a dark roof for steep slope orientations. The parameters used in the calculation were a) minimum insulation required by IECC for each city, b) high cost of electricity, c) average air conditioning efficiency, d) non-electric heating and e) average heating system efficiency. An average roof size of 2800 $ft^2$ was used, per NAHB statistics.

- *Energy and Cost Savings.* The results from the DOE Calculator are shown below:

| | Cooling Savings/year ($/ft^2$) | | Annual Dollar savings | |
|---|---|---|---|---|
| City | TSR 0.25 | TSR 0.40 | TSR 0.25 | TSR 0.40 |
| Los Angeles | 0.0037 | 0.0084 | $10.36 | $23.52 |
| San Francisco | 0.0006 | 0.0013 | $ 1.68 | $ 3.64 |
| San Diego | 0.0054 | 0.0124 | $15.12 | $34.72 |

The result show that the differential advantage of a roof with TSR 0.40 compared to TSR 0.25 is less than $20/year, even in the warmer climate of San Diego. Yet, a requirement of TSR 0.40 would eliminate many colors in the prepainted metal roofing industry. Popular earth tone and vibrant colors like red, blue, green, brown and gray would not meet the prescriptive requirement of TSR=0.40. The lighter colors that could meet a TSR=0.40 requirement would have minimal savings to the homeowners when compared to the darker colors possible with a lower TSR requirement.

- *Cost-effectiveness.* Prepainted metal roofing products can meet the TSR = 0.25 prescriptive requirement even at dark colors. The incremental cost for the paint systems containing the special cool pigments is insignificant, making all color cost effective as a cool roof product. The major producers of cool paint systems for the metal construction industry have stated that there is no price premium for these systems.

- *Modeling Rules or Algorithms.* The calculations were based on the DOE Steep Slope Roof Energy savings calculator. The modeling is not required for the 2008 revision cycle of Title 24. It is presented in this template to support the proposal to establish one standard TSR prescriptive requirement for all types of roofing products.

# Recommendations

We are proposing the following revisions to Sections 118 and 143. Subsections not listed are not changed.

## *SECTION 118 – MANDATORY REQUIREMENTS FOR INSULATION AND COOL ROOFS*

(i) **Mandatory Requirements for Cool Roofs.** In order to qualify for compliance credit as a cool roof or meet the requirements of Section 143 (a) 1 or 149 (b) 1 B, a cool roof shall be certified and labeled according to the requirements of Section 10-113 and meet the appropriate conditions ~~1 or 2 and, for liquid applied roofing products, 3~~ below.

~~1.Any roofing product with an initial thermal emittance greater than or equal to 0.75 when tested in accordance with CRRC-1 shall have a minimum initial solar reflectance of 0.70 when tested in accordance with CRRC-1.~~

~~2. **EXCEPTION to Section 118 (i) 1:** For low-rise residential buildings, concrete tile (as defined in ASTM C55) and clay tile (as defined in ASTM C1167) roofing products shall have a minimum initial thermal emittance of 0.75 and a minimum initial solar reflectance of 0.40 when tested in accordance with CRRC-1.~~

~~3.Any roofing product with a minimum initial thermal emittance $\varepsilon_{initial}$ less than 0.75 when tested in accordance with CRRC-1, including but not limited to roof products with metallic surfaces, shall have a minimum initial solar reflectance of $0.70 + 0.34 * (0.75 - \varepsilon_{initial})$ when tested in accordance with CRRC-1.~~

~~4. 3. Liquid applied roof coatings applied in the field as the top surface of a roof covering shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements listed in TABLE 118-C.~~

~~5. **EXCEPTION 1 to Section 118 (i) 3:** Aluminum pigmented asphalt roof coatings shall meet the requirements of ASTM D2824 or ASTM D6848 and be installed as specified by ASTM D3805.~~

~~1. **EXCEPTION 2 to Section 118 (i) 3:** Cement based roof coatings shall be applied at a minimum dry mil thickness of 30 mils when installed over a capsheet surface, 40 mils when installed over a metal surface, and 200 mils when installed over a rock or gravel surface. Cement based roof coatings shall contain a minimum of 20% cement, and shall meet the requirements of ASTM D822.~~

1. Low-sloped Roofs

   a. Any low-sloped roofing product with a 3-year aged emittance, $\varepsilon_{aged}$, greater than or equal to 0.75 shall have a 3-year aged solar reflectance, $\rho_{aged}$, greater than or equal to 0.55.

   b. Any low-sloped roofing product with a 3-year aged emittance, $\varepsilon_{aged}$, less than 0.75 shall have a 3-year aged solar reflectance,

   $$\rho_{aged} \geq 0.55 + 0.24 * (0.75 - \varepsilon_{aged})$$

2. Steep-sloped Roofs

   a. Any steep-sloped roofing product with a 3-year aged emittance, $\varepsilon_{aged}$, greater than or equal to 0.75 shall have a 3-year aged solar reflectance, $\rho_{aged}$, greater than or equal to 0.25.

   b. Any steep-sloped roofing product with a 3-year aged emittance, $\varepsilon_{aged}$, less than 0.75 shall have a 3-year aged solar reflectance,

   $$\rho_{aged} \geq 0.25 + 0.38 * (0.75 - \varepsilon_{aged})$$

3. Liquid Field-applied Roof Coatings

In addition to meeting the requirements of either 118 (i) 1 or 118 (i) 2, liquid roof coatings applied in the field as the top surface of a roof covering shall be applied....

[Same language that has finally been adopted for other performance properties]

4. Aged Property Determination

The three year aged solar reflectance, $\rho_{aged}$, and the three year aged thermal emittance, $\varepsilon_{aged}$, shall be established as follows:

a. If the CRRC-1 three year aged values are for solar reflectance and thermal emittance have been certified, these values shall be used.

b. If the CRRC-1 initial values for solar reflectance and thermal emittance have been certified, and the three year aged rating is in process as required by the CRRC-1 procedure, the three year aged values shall be estimated from the CRRC-1 initial values as follows:

1. $\rho_{aged} = 0.2 + 0.7 * (\rho_{initial} - 0.2)$

2. $\varepsilon_{aged} = \varepsilon_{initial}$

c. If the initial values have not been certified and labeled according to CRRC-1, the product shall be assigned a default three-year aged solar reflectance of 0.10 and a default three-year aged thermal emittance of 0.75.

EXCEPTIONS to Section 118(i):

1. For low-rise residential buildings with low-sloped roofs, the cool roof prescriptive requirements are waived in Climate Zones 1 through 9 and 12.

2. For low-rise residential buildings with steep-sloped roofs, the cool roof prescriptive requirements are waived in Climate Zones 1 through 8.

3. For nonresidential buildings with low-sloped roofs, the cool roof prescriptive requirements are waived in Climate Zones 1 through 6, 11, 12 and 16.

***SECTION 143 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES***

A building complies with this section by being designed with and having constructed and installed either (1) envelope components that comply with each of the requirements in Subsection (a) for each individual component and the requirements of Subsection (c) where they apply, or (2) an envelope that complies with the overall requirements in Subsection (b) and the requirements of Subsection (c) where they apply. When making calculations under Subsection (a) or (b), all of the rules listed in Section 141 (c) 1, 4, and 5 shall apply.

(a) **Envelope Component Approach.**

1. **Exterior roofs and ceilings.** Exterior roofs and ceilings shall:

A. ~~For nonresidential buildings with low-sloped roofs, meet~~ Meet the requirements of ~~either~~ 118 (i) 1 for low-sloped roofs, or 118 (i) 2 for steep-sloped roofs. In addition, ~~and for~~ liquid field-applied roof coatings shall meet the requirements of; Section 118 (i) 3; and

~~**EXCEPTION to Section 143 (a) 1 A:** Any roofing product with a minimum initial thermal emittance $\varepsilon_{initial}$ less than 0.75 when tested in accordance with CRRC-1, including but not limited to roof products with metallic surfaces, if that roofing product has a minimum initial solar reflectance of $0.70 + 0.34 * (0.75 - \varepsilon_{initial})$ when tested in accordance with CRRC-1.~~

(b) **Overall Envelope Approach**

2. **Overall heat gain.** The overall heat gain of the overall envelope of the proposed building, $HG_{prop}$ as calculated with EQUATION 143-E, shall be no greater than the overall heat gain of the overall envelope of a standard building, $HG_{std}$

as calculated with EQUATION 143-D. In making the calculations, it shall be assumed that the orientation and area of each envelope component of the standard building are the same as in the proposed building.

*EQUATION 143-D STANDARD BUILDING HEAT GAIN*

$$HG_{std} = \sum_{i=1}^{nW}\left(A_{Wi} \times U_{Wi_{std}} \times TF_i\right) + \sum_{i=1}^{nF}\left(A_{Fi} \times U_{Fi_{std}} \times TF_i\right) + \sum_{i=1}^{nR}\left(A_{Ri} \times U_{Ri_{std}} \times TF_i\right)$$
$$+ \sum_{i=1}^{nG}\left(A_{Gi} \times U_{Gi_{std}} \times TF_i\right) + \sum_{i=1}^{nS}\left(A_{Si} \times U_{Si_{std}} \times TF_i\right) + \sum_{i=1}^{nG}\left(WF_{Gi} \times A_{Gi} \times RSHG_{Gi_{std}}\right) \times SF$$
$$+ \sum_{i=1}^{nS}\left(\mathrm{WF_{Si}} \times A_{Si} \times SHGC_{Si_{std}}\right) \times SF + \sum_{i=1}^{nR}\left(\mathrm{WF_{Ri}} \times A_{Ri} \times U_{Ri_{std}} \times \left[\text{~~1 – (0.2 + 0.7[}\rho_{Ri_{std}} \text{ – 0.2])~~}\right]\left[1 - \rho_{Ri_{std}}\right]\right) \times SF$$

**WHERE:**

$\rho_{Ri_{std}}$ = ~~Initial~~ Three-year aged solar reflectance of the roofing product for the corresponding $A_{Ri}$. The roof of the standard building has a~~n initial~~ three-year aged solar reflectance of: ~~0.70 for nonresidential buildings with low-sloped roofs and an initial solar reflectance of 0.30 for nonresidential buildings with high-sloped roofs, for high-rise residential buildings, and for guest rooms of hotel/motel buildings.~~
0.55 for low-sloped roofs
0.25 for steep-sloped roofs

*EQUATION 143-E PROPOSED BUILDING HEAT GAIN*

$$HG_{prop} = \sum_{j=1}^{nW}\left(A_{Wj} \times U_{Wj_{prop}} \times TF_j\right) + \sum_{j=1}^{nF}\left(A_{Fj} \times U_{Fj_{prop}} \times TF_j\right) + \sum_{j=1}^{nR}\left(A_{Rj} \times U_{Rj_{prop}} \times TF_j\right)$$
$$+ \sum_{j=1}^{nG}\left(\mathrm{A_{Gj}} \times U_{Gj_{prop}} \times TF_j\right) + \sum_{j=1}^{nS}\left(A_{Sj} \times U_{Sj_{prop}} \times TF_j\right) + \sum_{j=1}^{nG}\left(WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j\right) \times SF$$
$$+ \sum_{j=1}^{nS}\left(WF_{Sj} \times A_{Sj} \times SHGC_{Sj_{prop}}\right) \times SF + \sum_{j=1}^{nR}\left(WF_{Rj} \times A_{Rj} \times U_{Rj_{prop}} \times \left[\text{~~1 – (0.2 + 0.7[}\rho_{Ri_{std}} \text{ – 0.2])~~}\right]\left[1 - \rho_{Ri_{prop}}\right]\right) \times SF$$

**WHERE:**

$\rho_{Ri_{prop}}$ = The ~~initial~~ three-year aged solar reflectance of the proposed design roofing product for the corresponding $A_{Rj}$, as certified and labeled according to the requirements of Section 10-113. If the roofing product has an emittance less than 0.75 the value shall be calculated by the following equation:

$\rho_{Ri_{prop}}$ = -0.448 + 1.121 * R +0.524 * E Note, this equation needs to be updated, as noted in Ref. [1].

Where
R = reflectance of the roofing product
E = emittance of the roofing product
The calculated value of $\rho_{Ri_{prop}}$ from the above equation shall not be larger

than R or less than 0.10.
If the proposed design roofing product used has not been certified and labeled according to the requirements of 10-113 and/or does not meet the requirements of Section 118 (i) 3, the proposed design ~~initial~~ three-year aged solar reflectance shall be 0.10 ~~for nonresidential buildings with low-sloped roofs, or 0.30 for nonresidential buildings with high-sloped roofs, high-rise residential buildings, and guest rooms in hotel/motel buildings~~.

# Material for Compliance Manuals

Appropriate updates to the compliance manuals would have to be evaluated. This has not been included in this proposal at this time.

# Bibliography and Other Research

(1) PIER Report: Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24, May 17, 2006.

(2) Energy Action Plan II, Implementation Roadmap for Energy Policies, California Energy Commission, September 21, 2005.

(3) Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Steep-Sloped Nonresidential Roofs in Title 24, Pacific Gas & Electric and Lawrence Berkeley National Laboratory, May 18, 2006.

(4) Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements, Code Change Proposal, Pacific Gas and Electric Company, May 16, 2002.

(5) Miller, W. A., Desjarlais, A.O., Akbari, H., Levenson, R., Berdahl, P. and Scichille, R.G. 2004. "Special IR Reflective Pigments Make a Dark Roof Reflect Almost Like a White Roof," in *Thermal Performance of the Exterior Envelopes of Buildings, IX,* proceedings of ASHRAE THERM IX, Clearwater, FL., Dec. 2004.

(6) DOE Steep Slope Roof Energy Savings Calculator:
http://www.ornl.gov/sci/roofs+walls/SteepSlopeCalc/index.htm