



## ROOF DESIGN RESOURCE FOR IMPROVED ENERGY EFFICIENCY AND HEAT ISLAND REDUCTION IN ARIZONA

The purpose of this information is to assist designers and specifiers in research efforts of roofs so as to enhance their energy efficiency while reducing heat islands in Arizona. This document is intended to be a resource and an aid, not a one-stop shop with all the answers.

- The “Roof Design Resource” is based on current Codes and Standards as promulgated. These Codes and Standards may not have been adopted in whole or part by the agency having authority over the property/location you are working on. You will need to verify current Codes and Standards based on the location of your project.
- This resource is based on projects with a roof area of 6,000 square feet or greater.
- Design based on published Codes and Standards (may not be applicable to your project at this time).
- Design based on code minimums as required for energy savings versus requirements of LEED design parameters.

### DEFINITIONS

**Heat island:** The term heat island refers to urban and suburban air and surface temperatures that are higher than nearby rural areas.

**Heat island effect:** This phenomenon describes urban and suburban air and surface temperatures that are 2 to 10°F (1 to 6°C) hotter than nearby rural areas. Elevated temperatures can impact communities by increasing peak energy demand, air conditioning costs, air pollution levels, and heat-related illness and mortality.

**Urban heat island effect:** A measurable increase in ambient urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure. The heat island effect can result in significant temperature differences between rural and urban areas. As population centers grow they tend to modify a greater and greater area of land and have a corresponding increase in average temperature.

### CODES

#### International Building Code

The International Building Code (IBC) is published every three years. The IBC establishes minimum regulations for building systems and is compatible with all International Codes published by the International Code Council (ICC). The IBC is available for adoption by local and regional jurisdictions in accordance with proceedings establishing the jurisdiction’s laws. Chapter 15 of the IBC pertains to Roofing Definitions, Performance Requirements, Fire Classifications, Materials, Minimum Requirements and Insulation amongst others, including required fire classification and wind uplift resistance.

#### International Energy Conservation Code

The International Energy Conservation Code (IECC) addresses energy conservation in the design of energy efficient building envelopes, the installation of energy efficient mechanical, lighting and power systems through requirements emphasizing performance. The IECC establishes minimum regulations for energy efficient buildings using prescriptive and performance-related provisions. The IECC is fully compatible with all International Codes published by the international Codes Council (ICC). The IECC is available for adoption by local and regional jurisdictions in accordance with proceedings establishing the jurisdiction’s laws. Chapter 5 covers commercial energy efficiency including: insulation requirements for walls and roofs, insulation and limits of fenestrations.

#### International Mechanical Code

The International Mechanical Code (IMC) addresses the design and installation of mechanical systems emphasizing performance. The IMC establishes minimum regulations for mechanical systems using prescriptive and performance related provisions. The IMC is fully compatible with all International Codes. The IMC intends to establish provisions consistent with the scope of the mechanical code that adequately protects public health, safety and welfare. The IMC is available for adoption by local and regional jurisdictions in accordance with proceedings establishing the



jurisdiction's laws. Not only does the Code include mechanical equipment, venting, hydronic piping, and fuel storage, chapter fourteen relates to Solar Systems.

#### **Title 24 by California Energy Commission**

This summary is cited for potential impact; not for its immediate impact on Arizona.

The revisions to the 2005 Title 24 California Energy Standards are due to be adopted in 2008 for implementation in 2009. The new requirements are more stringent than the 2005 Code.

Title 24 requires Cool Roofs in California Zones 2-15. The high mountain areas like Eureka and Lake Tahoe are exempt.

The Code is designed to reduce energy consumption in conditioned commercial space. The requirements are different for Steep and Low Sloped roofs. (Not adapted yet)

#### **Current Requirements:**

##### **Low Slope Non-Residential Conditioned Space ( $\leq$ 2:12 inch pitch)**

- 1) Minimum 3 year aged solar reflectance of 0.55.
- 2) Minimum 3 year aged solar emittance of 0.75 or have a minimum SRI of 65.
- 3) Products which do not have the three year test results can do an alternative calculation to show they "should" comply however all products will have to submit to the test to prove compliance or they will have those products removed from the Cool Roof Rating Council listings.
- 4) Green roofs are not exempt.
- 5) Roofs covered with PV arrays will need to provide the alternative efficiency method calculations to prove overall building envelope efficiency in excess of minimum requirements.

##### **Steep Slope Non-Residential Conditioned Space ( $>$ 2:12 inch pitch)**

- 1) Zones 1 and 16 are exempt from the Title 24 requirements (Eureka and Lake Tahoe).
- 2) Minimum 3 year aged solar reflectance of 0.25.
- 3) Minimum thermal emittance of 0.75 or a minimum SRI of 25.

#### **American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.**

##### **ASHRAE 90.1 - 2007**

The American Society of Heating, Refrigerating and Air-Conditions Engineers, Inc. (ASHRAE) publishes the ASHRAE STANDARD which is now called ANSI/ASHRA/IESNA Standard 90.1-2007 (Commonly called ASHRAE 90.1-2007). ASHRAE 90.1 is an Energy Standard for Buildings Except Low-Rise Residential Buildings. The standard is a national consensus standard, updated several times annually. The 2006 and earlier editions of the IECC do not reference the 2007 of ASHRAE 90.1, but is included in the 2009 edition.

A municipal, county or state jurisdiction may elect to adopt a new edition of the IECC as a portion of the International Commercial Code or International Residential Code. This same government body may choose to modify the energy code prior to adoption. In addition the government body may choose to interpret or implement the code in their own way. The ASHRAE STANDARD 90.1-2007 is the consensus standard for most Mechanical Codes.

There is no national or international code requirement for roof membrane reflectance as of this writing. California Title 24 has requirements for roof reflectance in their 2005 code. Furthermore, they restated those standards on Low Slope Non-residential Controlled Temperature space roofs for all but 2 of their 16 zones in their 2008 code. Title 24 calls for roof reflectance standards on other forms of buildings.



**ASHRAE 90. 1-07 5.5**  
**Buildings with Conditioned Air**  
**Insulation Entirely Above Roof Deck**

**OPAQUE ROOF ASSEMBLIES**

	<u>Min. R Value</u>	<u>Metal</u>	<u>Attic</u>
<b>Arizona</b> <b>ZONE 2 B/Dry</b> Maricopa, Pima, Pinal, Yuma	R-20	R-19	R-38
<b>Arizona</b> <b>Zone 4B/Dry</b> Gila, Yavapai	R-20	R-19	R-38
<b>Arizona</b> <b>Zone 5 B/Dry</b> Apache, Navajo, Coconino	R-20	R-19	R-38

**SKYLIGHTS**

	<u>SHGC*</u>
SL / Curb / Glass	
0-2% of Roof	0.49
2.1 -5.0%	0.39
SL / Curb / Plastic	
0 - 2% of Roof	0.77
2.1- 5.0%	0.77
SL / w/o Curb	
0 - 2%	0.49
2.1% - 5%	0.39

SL/ total area shall be less than 5% of gross roof area

SL Curbs shall be insulated to the level of the roof with insulation entirely above the deck or to R-5 R-5 whichever is less.

\*SHGC = Solar Heat Gain Coefficient



### US Green Building Council

The US Green Building Council and their LEED program inspire building designers, contractors and owners to create more energy efficient buildings. Significant points toward program recognition are awarded for building designed and built beyond the minimum energy efficiency standards. LEED 3.0 adopts a significant increase to the base line via the ASHRAE 90.1 - 2007 standard.

The American Institute of Architects (AIA) recognizes that buildings are responsible for approximately half of all US energy consumption and CO<sub>2</sub> emissions annually. Building operations alone, i.e., heating, cooling, lighting, hot water and the outlet loads, account for 43% of total US CO<sub>2</sub> emissions and 76% of total US electricity consumption. Therefore, to have any real impact on climate change, it is essential to address CO<sub>2</sub> emissions in the Building Sector. Therefore the AIA has announced "Architecture 2030" and "The 2030 Challenge". The 2030 Challenge will mean a further reduction of 30% in heat loss heat gain from the ASHRAE 90.1-2007 Standard.

ASHRAE, the US Green Building Council and many other agencies have endorsed the multi step reduction in energy consumption and CO<sub>2</sub> emissions. It is generally believed that the combination of the Public Private leadership in emission control and energy reduction through Code and equipment efficiencies will dramatically reduce energy consumption between now and 2030.

As energy codes require greater quantities of insulation, dark or non-reflective membranes can be subject to higher absorption temperatures and greater potential mechanical load in an assembly with the insulation between the deck and the roofing assembly. Lighter colors and reflective membranes can reduce loads on the mechanical cooling system.

### Ballasted Roofing Systems

Research conducted by the Oak Ridge National Laboratory<sup>1</sup> (ORNL) indicated that over time medium (17 lb/ft<sup>3</sup>) and heavy (24 lb/ft<sup>3</sup>) ballasted roofing systems performed at the same or better level of thermal performance, compared to the rated Energy Star cool roof products such as the white TPO membrane.

Ballast is an integral part of Protected Membrane Roofing (PMR). In a PMR assembly the roof membrane is protected by an insulation that goes above (outside) the membrane. The insulation is protected from UV and kept in place by the ballast. In a PMR assembly, the membrane is protected from thermal, ultraviolet, and physical abuse. The membrane temperature is within a few degrees of the interior temperature. Because the membrane is inside the controlled temperature environment, membrane lifetimes have been found to dramatically increase. Some PMR membranes at Michigan State University recently celebrated their 40-year anniversary. While Protected Membrane Roofing may be more expensive in original cost, it is well documented PMR assemblies can provide long service life and lower life cycle costs for the building owner. For those that are so inclined, a PMR may also offer additional LEED point potential.

Based on the ORNL study, ASHRAE 90.1-2007 Addendum recognized a ballasted roof as a type of cool roof in addition to the traditional types of cool roofs defined by reflectivity and Solar Reflectance Index. Additional code bodies are being asked to consider adding this provision in their roofing section.<sup>1</sup>

## STANDARDS and ASSOCIATIONS

AAMA American Architectural Manufacturers Association; [www.aamanet.org](http://www.aamanet.org)

AAMA 101/I.S.2/a44-05 Specs for windows – doors – skylights

ANSI American National Standards Institute; [www.ansi.org](http://www.ansi.org)

ARI Air Conditioning and Refrigeration Institute; [www.ari.org](http://www.ari.org)

<sup>1</sup> "Evaluating the Energy Performance of Ballasted Roof Systems," ORNL Report Number UF-04- 96, prepared for Single Ply Roofing Industry (SPRI), by Andre Desjarlais Thomas Petrie and Jerald Atchley from Building Envelope Program, Oak Ridge National Laboratory, Richard Gillenwater, Carlisle Syntec, Inc. and David Roodvoets, SPRI, Inc., April 2008.



ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; [www.ashrae.org](http://www.ashrae.org)

ASHRAE 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings

ASTM International; [www.astm.org](http://www.astm.org)

ASTM C 1371-04a, Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emisometers: This test method covers a technique for determination of the emittance of typical materials using a portable differential thermopile emisometer. The purpose of the test method is to provide a comparative means of quantifying the emittance of opaque, highly thermally conductive materials near room temperature as a parameter in evaluating temperatures, heat flow, and derived thermal resistances of materials.

ASTM C 1549-04, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer: This test method covers a technique for determining the solar reflectance of flat opaque materials in a laboratory or in the field using a commercial portable solar reflectometer. The purpose of the test method is to provide solar reflectance data required to evaluate temperature and heat flows across surfaces exposed to solar radiation.

ASTM E 408-71 (2008), Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques: This standard describes how to measure total normal emittance of surfaces using a portable inspection-meter instrument. The test methods are intended for large surfaces where non-destructive testing is required. See the standard for testing steps and discussion of thermal emittance theory.

ASTM E 903-96, Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres: Referenced in ENERGY STAR® roofing standard, this test method uses spectrophotometers and need only be applied for initial reflectance measurement. Methods of computing solar-weighted properties from the measured spectral values are specified. This test method is applicable to materials having both spectral and diffuse optical properties. Except for transmitting sheet materials that are inhomogeneous, patterned, or corrugated, this test method is preferred over Test Method E1084. The ENERGY STAR roofing standard also allows the use of reflectometers to measure solar reflectance of roofing materials. See the roofing standard for more details. (NOTE: This test method has been withdrawn with no replacement)

ASTM E 1918-06, Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field: This test method covers the measurements of solar reflectance of various horizontal and low-sloped surfaces and materials in the field, using a pyranometer. The test method is intended for use when the sun angle to the normal from a surface is less than 45 degrees.

ASTM E 1980-01, Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces: This standard describes how surface reflectivity and emissivity are combined to calculate a Solar Reflectance Index (SRI) for a roofing material or other surface. The standard also describes a laboratory and field testing protocol that can be used to determine SRI.

CRRC Cool Roof Rating Council; [www.coolroofs.org](http://www.coolroofs.org)

DOE U.S. Department of Energy; [www.energy.gov](http://www.energy.gov)

DOE/EIA-0376 State Energy Prices and Expenditure Report

EPA Environmental Protection Agency; [www.epa.gov](http://www.epa.gov)

Energy Star reflective roof program; [www.energystar.gov/index.cfm?c=roof\\_prods.pr\\_roof\\_products](http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products)

ICC International Code Council, Inc.; [www.iccsafe.org](http://www.iccsafe.org)



NFRC National Fenestration Rating Council; [www.nfrc.org](http://www.nfrc.org)

NFRC 100-2004, Procedure for Determining Fenestration Product U-Factors (Referenced in 2006 IECC Section 102.1.3)

NFRC 200-2004, Procedures for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance of Normal Incidence (Referenced in 2006 IECC Section 102.1.3)

NFRC 400-2004, Procedure for Determining Fenestration Product Air Leakage (Reference in 2006 IECC Sections 402.4.2 and 502.4.1)

SMACNA Sheet Metal and Air Conditioning Contractors' National Association; [www.smacna.org](http://www.smacna.org)

UL Underwriters Laboratories Inc.; [www.ul.com](http://www.ul.com)

## CERTIFICATIONS

Currently there are two national roof reflectance rating programs in the United States: the Cool Roof Rating Council's (CRRC) Product Rating Program and the Environmental Protection Agency's ENERGY STAR® Reflective Roof program.

### Energy Star®

Manufacturers can choose to rate their products with the ENERGY STAR label as long as they meet or exceed ENERGY STAR's minimum specifications for solar reflectance without compromising product quality and performance. Manufacturers voluntarily sign an agreement with ENERGY STAR called a Partnership Agreement allowing them to place the ENERGY STAR label on the packaging of qualifying roof products. The label can also be used in product promotions and advertising of the qualified products. The ENERGY STAR program accepts ratings that meet or exceed their specifications provided either from the manufacturer's own testing or from the CRRC Product Rating Program.

### Cool Roofing Rating Council

The CRRC does not define what is a "cool roofing product" or set minimum requirements. The CRRC maintains a credible, third party rating system to measure and label the radiative properties of roofing materials. Manufacturers can label their products with solar reflectance and thermal emittance values by having them tested by CRRC accredited independent testing laboratories. The CRRC Rated Products Directory is provided on their website. Not all products on the CRRC Rated Products Directory are "cool" as defined by any particular code body or program.

The CRRC requires independent testing of roofing products and therefore does not accept the ENERGY STAR ratings. The State of California Title 24 had accepted the ENERGY STAR ratings in the past, but no longer. All products must be rated with the CRRC.

LEED for New Construction and Major Renovation (LEED-NC) references the CRRC as a source of product ratings, but does not require the product to be CRRC-rated. LEED-NC also allows products that are ENERGY STAR labeled that meet the LEED minimum Solar Reflectance Index.

## RESOURCES

Arizona Cool Roof Council  
7261 W. Bloomfield Rd.  
Peoria, AZ 85381  
623.878.7117  
[info@azcoolroof.com](mailto:info@azcoolroof.com)  
<http://www.azcoolroof.com/>

*A clearinghouse for information related to the design and construction of cool roofs and an educational resource for roof designers, installers, and building owners.*



Arizona State University  
National Center of Excellence  
SMART Innovations for Urban Climate and Energy  
<http://asusmart.com/urbanclimate.php>

*The National Center of Excellence on SMART Innovations serves to develop use-inspired fundamental and applied research solutions for an urbanizing planet.*

B and B Consulting  
100435 N. Nicklaus Dr  
Fountain Hills, AZ 85268  
[bauerrdb@cox.net](mailto:bauerrdb@cox.net)

*Low Slope roof resign and consulting firm, recognized in four states as a roofing expert. Expert witness in CD cases and casualty claims.*

California Energy Commission  
Media and Public Communications Office  
1516 Ninth Street, MS-29  
Sacramento, CA 95814-5512  
<http://www.energy.ca.gov/title24/coolroofs/index.html>

Cool Roof Rating Council  
1610 Harrison Street  
Oakland, CA 94612  
<http://www.coolroofs.org>  
<http://www.coolroofs.org/products/search.php>

*The Cool Roof Rating Council (CRRC) is an independent and non-biased organization that has established a rating system for displaying accurate radiative property data on the outermost layer of roof surfaces.*

Dow Chemical Company  
J. Michael Lentz  
Sales  
679 W. Littleton Blvd., Suite #206  
Littleton, CO 80120-2355  
Phone: 303.794.9140  
Fax: 303.794.9169  
[jmlentz@dow.com](mailto:jmlentz@dow.com)  
*Building Solutions.*

Dunn-Edwards Corporation  
Tim Garver, CSI, CDT  
1872 E. Broadway Rd.  
Tempe, AZ 85282  
Phone: 602.714.7280  
Fax: 480.894.2044  
[tim.garver@dunnedwards.com](mailto:tim.garver@dunnedwards.com)  
<http://www.dunnedwards.com>  
*Paints and Coatings.*

Energy Star  
US EPA  
ENERGY STAR Hotline (6202J)  
1200 Pennsylvania Ave NW  
Washington, DC 20460  
<http://www.energystar.gov>  
<http://www.energystar.gov/ia/partners/publications/pubdocs/2007%20CPPD%204pg.pdf>  
[http://www.energystar.gov/ia/products/prod\\_lists/roofs\\_prod\\_list.pdf](http://www.energystar.gov/ia/products/prod_lists/roofs_prod_list.pdf)

*Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy.*



EnviroCoatings, Incorporated  
Donald Klaus  
Phone: 619.794.6935  
[dklaus@pacbell.net](mailto:dklaus@pacbell.net)  
<http://www.envirocoatings.com>  
*Ceramic Thermal Barrier Performance Coatings.*

FBE Products  
Joe Volinsky, CSI  
Phone: 623.516.8186  
Fax: 623.516.0846  
Cell: 480.580.1127  
[fbiaz1@msn.com](mailto:fbiaz1@msn.com)  
[www.firestonebp.com](http://www.firestonebp.com)  
[www.unaclad.com](http://www.unaclad.com)  
[www.nationalcoatings.com](http://www.nationalcoatings.com)  
*FBE Products represents Firestone Building products, Firestone Metal Products and National Coatings Cool Roof Systems.*

Lawrence Berkeley National Laboratory – Berkeley Lab  
Berkeley, CA  
<http://www.lbl.gov/>  
*A U. S. Department of Energy National Laboratory operated by the University of California, Berkeley, CA.*

National Roofing Contractors Association  
10255 W. Higgins Road  
Suite 600  
Rosemont, IL 60018-5607  
Telephone: 847.299.9070  
Fax: 847.299.1183  
<http://www.nrca.net>  
*An association of roofing, roof deck, and waterproofing contractors; industry-related associate members; and international members worldwide.*

Oak Ridge National Laboratory  
P.O. Box 208  
Oak Ridge, TN 37831  
<http://www.ornl.gov/>  
*ORNL conducts basic and applied research and development to create scientific knowledge and technological solutions.*

The Reflective Roof Coatings Institute (RRCI)  
14 W Third Street  
STE 200  
Kansas City, MO 64152  
Phone: 816.472.8870  
Fax: 816.472.7765  
[info@reflectivecoatings.org](mailto:info@reflectivecoatings.org)  
*RRCI was organized to promote the benefits of reflective roof coatings in extending the life of roof systems while reducing energy consumption and demand for the building envelope.*

Single Ply Roofing Industry  
411 Waverley Oaks Road, Suite 331B  
Waltham, MA 02452  
<http://www.spri.org/>  
*SPRI is the recognized technical and statistical authority on the Single Ply Roofing Industry. SPRI provides a forum for its members to collectively focus their industry expertise and efforts on critical industry issues.*



The Twenty-One Tech Company, Incorporated  
Antonio J. Valdez  
5660 S. 32nd St., Ste. 105  
Phoenix, AZ 85040  
Phone: 480.812.8800  
Fax: 480.814.8576  
[tjv@twenty1tec.com](mailto:tjv@twenty1tec.com)  
<http://www.twenty1tec.com>  
*Building Solutions.*

United States Environmental Protection Agency  
Cool Roofs  
US Environmental Protection Agency  
1200 Pennsylvania Avenue, NW  
Mail Code 6205J  
Washington, DC 20460  
<http://epa.gov/heatisland/strategies/coolroofs.html>

### Prepared by the CSI Phoenix Chapter Technical Committee (2008 - 2009)

Chairman – Tim Garver, CSI, CDT  
[tim.garver@dunnedwards.com](mailto:tim.garver@dunnedwards.com)

Committee Members – Dick Bauer, CSI, CTRC  
[dickbauer@bandb-consulting.com](mailto:dickbauer@bandb-consulting.com)

Ronald L. Geren, CSI, CCS, CCCA, AIA, SCIP  
[ron@specsandcodes.com](mailto:ron@specsandcodes.com)

Mike Lentz  
[jmlentz@dow.com](mailto:jmlentz@dow.com)

Brian McClure, RA, CSI, CDT  
[bmclure@fmsolutions.net](mailto:bmclure@fmsolutions.net)

Steve Smith, CSI, AIA  
[stephen.smith@hdrinc.com](mailto:stephen.smith@hdrinc.com)

Tom Urich  
[section7marketing@netzero.com](mailto:section7marketing@netzero.com)