AZTechNotes
A Publication of the CSI Phoenix Chapter Technical Committee

Roof Design Resource for Improved Energy Efficiency and Heat Island Reduction in Arizona

1.0 Purpose

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.

2.0 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.

3.0 Codes

3.1 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.

3.2 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.

3.3 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.

3.4 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 (≤ 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.

3.5 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

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

SKYLIGHTS

	SHGC*
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

Skylights (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 whichever is less.

*SHGC = Solar Heat Gain Coefficient

3.6 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_2 emissions annually. Building operations alone, i.e., heating, cooling, lighting, hot water and the outlet loads, account for 43% of total US CO_2 emissions and 76% of total US electricity consumption. Therefore, to have any real impact on climate change, it is essential to address CO_2 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_2 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.

3.7 Ballasted Roofing Systems

Research conducted by the Oak Ridge National Laboratory[1] (ORNL) indicated that over time medium (17 lb/ft^3) and heavy (24 lb/ft^3) 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.[1]

[1] “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.

4.0 Standards and Associations

AAMA American Architectural Manufacturers Association; www.aamanet.org

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

ANSI American National Standards Institute; www.ansi.org

ARI Air Conditioning and Refrigeration Institute; www.ari.org

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.; www.ashrae.org

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

ASTM International; www.astm.org

ASTM C 1371-04a, Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers: This test method covers a technique for determination of the emittance of typical materials using a portable differential thermopile emissometer. 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 raditation.

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

DOE U.S. Department of Energy; www.energy.gov

DOE/EIA-0376 State Energy Prices and Expenditure Report

EPA Environmental Protection Agency; www.epa.gov

Energy Star reflective roof program; www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products

ICC International Code Council, Inc.; www.iccsafe.org

NFRC National Fenestration Rating Council; 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

UL Underwriters Laboratories Inc.; www.ul.com

5.0 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.

5.1 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.

5.2 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.

6.0 Resources

Arizona Cool Roof Council
7261 W. Bloomfield Rd.
Peoria, AZ 85381
623.878.7117
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
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.coofroofs.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
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
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
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
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
www.firestonebp.com
www.unaclad.com
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
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
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 Co.
Antonio J. Valdez
1000 N. Hamilton St. Suite C-5
Chandler, AZ 85225
Phone: 480.812.8800
Fax: 480.814.8576
tjv@twenty1tec.com
Building Solutions.

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

7.0 Acknowledgments

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

Chairman – Tim Garver, CSI, CDT
tim.garver@dunnedwards.com

Committee Members – Dick Bauer, CSI, CTRC
dickbauer@bandb-consulting.com

Mike Lentz
jmlentz@dow.com

Brian McClure, RA, CSI, CDT
bmcclure@fmsolutions.net

Steve Smith, CSI, AIA
stephen.smith@hdrinc.com

Tom Urich
section7marketing@netzero.com

Ronald L. Geren, CSI, CCS, CCCA, AIA, SCIP
ron@specsandcodes.com

Additional Information:

Author: See Section 7.0 Acknowledgements

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