TECHNICAL COMMITTEE

of the EU Cool Roofs Council

Project N°: IEE 07/475/S12.499428-Cool Roofs.

Assessment of International Standards for the Measurement and Determination of Solar and Thermal Properties

Eco-friendly cool roof technology

- Results from research activity between ENEA and private technology manufacturer

General information:

Technology developer: Laboratori Ecobios

- Assessment of product properties and product qualification: ENEA
- Date of issue (year): 2006

Aims and Objectives:

The use of bright colours for painting the building envelope of buildings is a trademark of vernacular Mediterranean architecture. This was an effective solution to reduce the cooling loads and ensure thermal comfort conditions in the built environment. The modern architecture often does not take into account these concepts and it is daily experimented the increase of cooling loads in residential and commercial buildings, and the thermal discomfort for occupants. Old design concepts merged with new technologies can improve the energy performance of buildings in the Mediterranean area and reduce the increasing heat island effect in large urban areas.

High reflective materials for the opaque components, especially the roof exposed to strong solar radiation, can be useful to reduce the cooling loads for several building typologies. Cool roof materials are characterised by high solar reflectance, to reflect the solar radiation during daytime, and high infrared emittance, to exchange away the heat stored into the structure at night. Respects to conventional materials, other characteristics are required: easy to clean, high durability in maintaining the original colour and resist to ageing phenomena.

Reflective coating also improve the quality of outdoor urban spaces more and more affected by the phenomenon know as *urban heat island effect*. This is the increase of air temperatures in cities respect to the surrounding countryside due to the high construction density, the limited green area, waste of public and private transport, waste of air conditioning systems and others cause.

This technology is crucial to fulfil energy and environment targets in times of global warming. This is recognised at European level, since EU funded the PROMOTION OF COOL ROOFS IN THE EU Project (www.coolroofs-eu.eu) in the framework of the Intelligent Energy Europe Programme.

A Short Description of the Technology:

Laboratori Ecobios (www.ecobios-solaria.it) produces a multi-mineral eco hydro-painting based on a mixture of milk and vinegar, obtained by Mediterranean grapes. The product is an eco-friendly solution for several roofing purposes. An important characteristic is the high solar reflectance (even for non-white colours, see the following figure) and the possibility of being applied practically on almost all the construction (wood, concrete, plaster, metal, glass and so on). It is also suitable for flat and tilted roofs. The first products were surface coatings consisting of several layers, to be prepared and applied on site. Latest technological developments led to the production of single plies to be directly fixed on the roof.

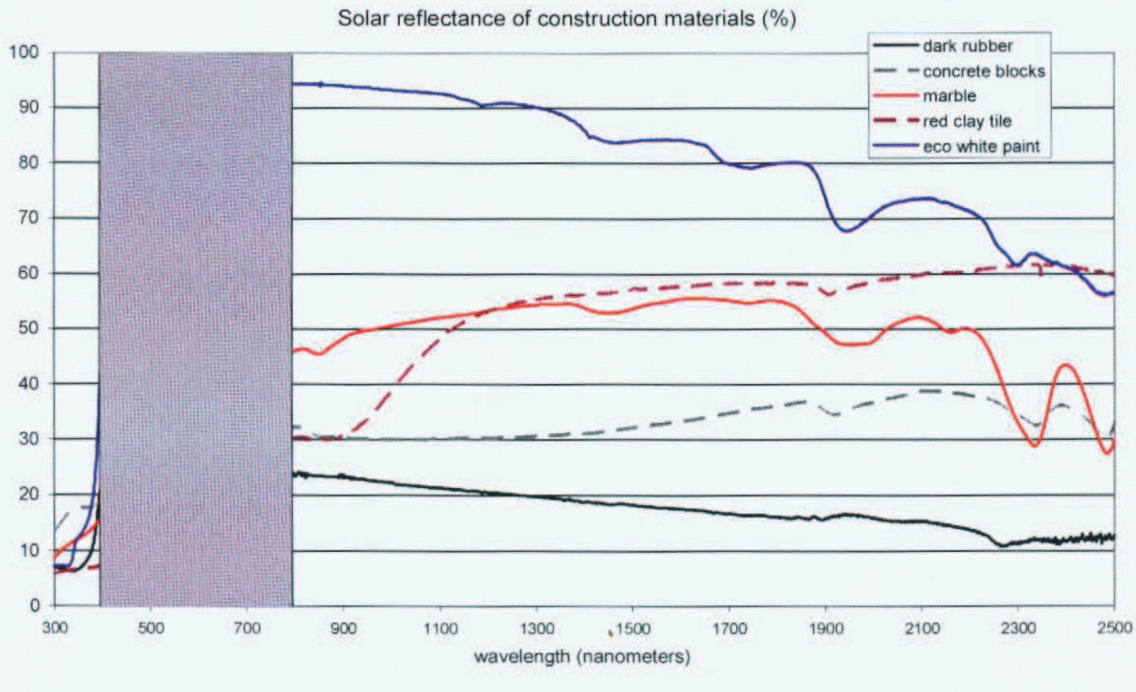


Figure Spectral reflectance of the eco white paint and most common construction materials

ECO BUILDING CLUB

RTD sheet

Innovative Technolog

- Cool roof paint and single layer

Eco-friendly cool roof technology

- Results from research activity between ENEA and private technology manufacturer

Once the roof or the other envelope components are treated with this product, most of the solar radiation impinging the building envelope is reflected away. This helps to keep the building environment cool during the summer time, which is becoming critical in terms of electric consumption and peak demand.

White paint on a flat roof

Sample	Light	Dark
	ρ_e(%)	ρ_e(%)
White	85.9	
Red	75.2	69.4
Yellow	80.6	77.7
Rose	69.3	61.7
Green	82.6	76.4
Grey	62.0	51.8

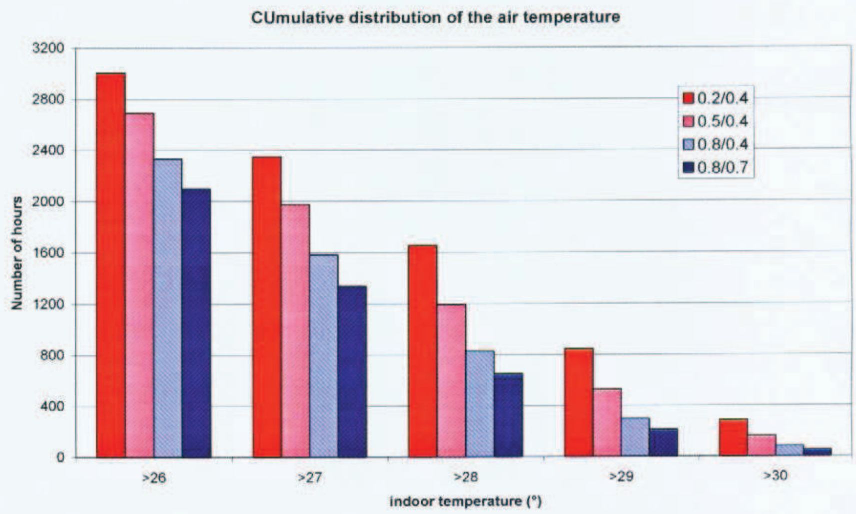
Solar reflectance of the different milk and vinegar paints

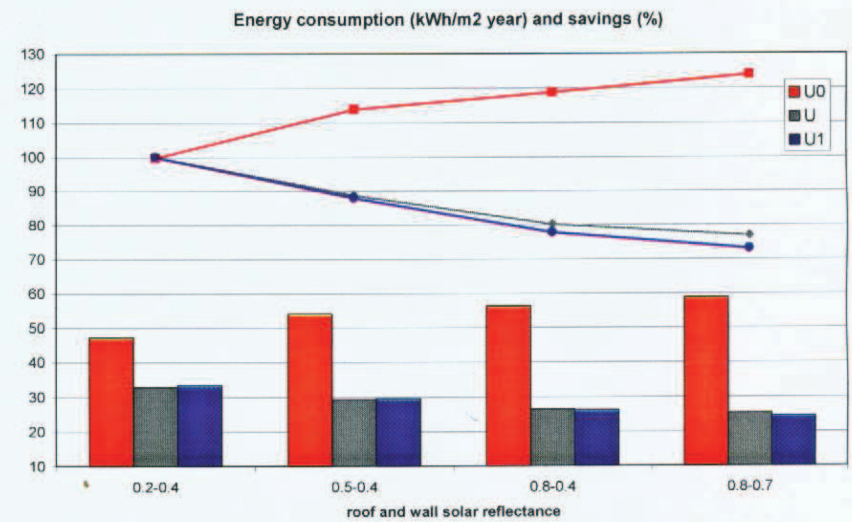
Results and Achievements

The various products were used to paint more than 700,000 square meters of roofs for: construction companies, residential buildings, public buildings, industry buildings.

Many numerical and experimental analyses were carried out to assess the potential energy savings deriving from application of cool roof technologies in residential and commercial buildings. The simulations were run using a dynamic tool (TRNSYS) for several climatic localities in the Mediterranean area, taking into account cooled and not cooled buildings.

Figures in right side report the results obtained from a single story house in Palermo. The upper figure presents the cumulative distribution function of the indoor air temperature with respect to the threshold values in X-axis during the summer time. The bars refer to the couple of solar reflectance values in the legend (left refers to the roof, right to the vertical walls). The lower figure shows the results of the same house with a cooling system installed (the roof solar reflectance as X-axis and the energy demand/consumption on the Y-axis). As a function of different solar reflectance (same couples of the left figure), the histogram graphs present energy consumption, expressed in kilowatt-hour per square meter per year, while the lines refer to the percentage of energy savings. This graph presents the results for three level of insulations: according to the Italian energy code (U in the legend), 20% more insulated than the standard (U1), no insulation (U0).





The project aims at promoting and widespread disseminating EU innovative Research and Technology Development and Demonstration results, as well as eco-sustainability criteria in building sector, which include:

- energy efficient building materials, components and systems not yet introduced into the building market or in their first market phase;
- innovative applications of heating/cooling and power supply technologies, combined with the use of renewable energy sources, in building sector;
- best EU demonstration eco-building projects.

The results show how the thermal and energy performance of residential building can be improved using this technology.

The application is promising for commercial building as well, since high internal and solar gains make more critical the impact of cooling demand in the overall energy performance of the building.

Possible application area:
Residential and commercial buildings. Cooled and not cooled buildings.

Reference: The research comes from a combined activity between a small enterprises and ENEA, public body operating in the energy efficiency sector. ENEA supplied manpower and knowledge, Ecobios supplied products and market experience.

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Paper prepared by ENEA, date published in 02/2009

Eco-Building Club: an innovative RTD&D results' promotion approach

Different from common market promotion approaches, where market operators are only simple message receivers, the project proposes an innovative approach: Eco-Building Club is a virtual round table, around which building market operators will be main actors for market penetration of research and demonstration results, through the following actions:

- determining what are more appropriated innovative RTD&D results for local market transferring;
- demonstrating the feasibilities of the research and demonstration results on real cases.

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Breathable
Number	:	74
Country	:	Italy
Product	:	sheath
Colour	:	**green**
Solar Reflectance%	:	81
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	43,9
Solar Reflectance Index	:	102

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Breathable
Number	:	77
Country	:	Italy
Product	:	sheath
Colour	:	**white**
Solar Reflectance%	:	87
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	40,8
Solar Reflectance Index	:	110

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Breathable
Number	:	75
Country	:	Italy
Product	:	sheath
Colour	:	**yellow**
Solar Reflectance%	:	82
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	43,4
Solar Reflectance Index	:	103

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Breathable
Number	:	71
Country	:	Italy
Product	:	sheath
Colour	:	**red**
Solar Reflectance%	:	77
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	46,1
Solar Reflectance Index	:	96

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Breathable
Number	:	69
Country	:	Italy
Product	:	sheath
Colour	:	**brown**
Solar Reflectance%	:	72
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	49,0
Solar Reflectance Index	:	88

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Washable
Number	:	72
Country	:	Italy
Product	:	sheath
Colour	:	**green**
Solar Reflectance%	:	78
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	45,8
Solar Reflectance Index	:	97

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Washable
Number	:	76
Country	:	Italy
Product	:	sheath
Colour	:	**white**
Solar Reflectance%	:	86
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	41,2
Solar Reflectance Index	:	109

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Washable
Number	:	73
Country	:	Italy
Product	:	sheath
Colour	:	**yellow**
Solar Reflectance%	:	80
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	44,5
Solar Reflectance Index	:	100

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Washable
Number	:	70
Country	:	Italy
Product	:	sheath
Colour	:	**red**
Solar Reflectance%	:	74
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	48,1
Solar Reflectance Index	:	91

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Ecobios Leùc** Washable
Number	:	68
Country	:	Italy
Product	:	sheath
Colour	:	**brown**
Solar Reflectance%	:	68
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	51,4
Solar Reflectance Index	:	82

ECOBIOS COOL ROOFING TECHNOLOGY

COOL ROOFS Intelligent Energy Europe

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Breathable
Number	:	49
Country	:	Italy
Product	:	membrane
Colour	:	**green**
Solar Reflectance%	:	83
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	42,9
Solar Reflectance Index	:	105

ECOBIOS COOL ROOFING TECHNOLOGY

COOL ROOFS Intelligent Energy Europe

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Breathable
Number	:	52
Country	:	Italy
Product	:	membrane
Colour	:	**white**
Solar Reflectance%	:	87
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	40,8
Solar Reflectance Index	:	110

ECOBIOS COOL ROOFING TECHNOLOGY

COOL ROOFS Intelligent Energy Europe

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Breathable
Number	:	50
Country	:	Italy
Product	:	membrane
Colour	:	**yellow**
Solar Reflectance%	:	84
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	42,8
Solar Reflectance Index	:	105

ECOBIOS COOL ROOFING TECHNOLOGY

COOL ROOFS Intelligent Energy Europe

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Breathable
Number	:	46
Country	:	Italy
Product	:	membrane
Colour	:	**red**
Solar Reflectance%	:	79
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	45,1
Solar Reflectance Index	:	99

ECOBIOS COOL ROOFING TECHNOLOGY

COOL ROOFS Intelligent Energy Europe

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Breathable
Number	:	43
Country	:	Italy
Product	:	membrane
Colour	:	**brown**
Solar Reflectance%	:	74
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	48,1
Solar Reflectance Index	:	91

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Washable
Number	:	47
Country	:	Italy
Product	:	membrane
Colour	:	**green**
Solar Reflectance%	:	79
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	45,1
Solar Reflectance Index	:	99

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Washable
Number	:	51
Country	:	Italy
Product	:	membrane
Colour	:	**white**
Solar Reflectance%	:	86
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	41,2
Solar Reflectance Index	:	109

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Washable
Number	:	48
Country	:	Italy
Product	:	membrane
Colour	:	**yellow**
Solar Reflectance%	:	82
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	43,7
Solar Reflectance Index	:	102

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Washable
Number	:	45
Country	:	Italy
Product	:	membrane
Colour	:	**red**
Solar Reflectance%	:	79
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	45,1
Solar Reflectance Index	:	99

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**EcobiosCLIMA** Washable
Number	:	44
Country	:	Italy
Product	:	membrane
Colour	:	**brown**
Solar Reflectance%	:	78
Infrared Emittance(-)	:	0,88
Temperature Rise (°C)	:	46,0
Solar Reflectance Index	:	96

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	: **SUNLIFE** Breathable
Number	: 59
Country	: Italy
Product	: paint
Colour	: **green**
Solar Reflectance%	: 79
Infrared Emittance(-)	: 0,89
Temperature Rise (°C)	: 45,0
Solar Reflectance Index	: 99

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	: **SUNLIFE** Breathable
Number	: 64
Country	: Italy
Product	: paint
Colour	: **white**
Solar Reflectance%	: 83
Infrared Emittance(-)	: 0,89
Temperature Rise (°C)	: 42,8
Solar Reflectance Index	: 105

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	: **SUNLIFE** Breathable
Number	: 61
Country	: Italy
Product	: paint
Colour	: **yellow**
Solar Reflectance%	: 81
Infrared Emittance(-)	: 0,89
Temperature Rise (°C)	: 44,3
Solar Reflectance Index	: 101

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	: **SUNLIFE** Breathable
Number	: 57
Country	: Italy
Product	: paint
Colour	: **red**
Solar Reflectance%	: 74
Infrared Emittance(-)	: 0,89
Temperature Rise (°C)	: 47,7
Solar Reflectance Index	: 92

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	: **SUNLIFE** Breathable
Number	: 66
Country	: Italy
Product	: paint
Colour	: **brown**
Solar Reflectance%	: 67
Infrared Emittance(-)	: 0,89
Temperature Rise (°C)	: 51,5
Solar Reflectance Index	: 82

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Solaria Universal** Breathable
Number	:	72
Country	:	Italy
Product	:	paint
Colour	:	**green**
Solar Reflectance%	:	82
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	43,7
Solar Reflectance Index	:	102

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Solaria Universal** Breathable
Number	:	67
Country	:	Italy
Product	:	paint
Colour	:	**white**
Solar Reflectance%	:	87
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	40,9
Solar Reflectance Index	:	110

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**Solaria Universal** Breathable
Number	:	63
Country	:	Italy
Product	:	paint
Colour	:	**yellow**
Solar Reflectance%	:	81
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	44,0
Solar Reflectance Index	:	102

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Solaria Universal** Breathable
Number	:	60
Country	:	Italy
Product	:	paint
Colour	:	**red**
Solar Reflectance%	:	79
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	45,1
Solar Reflectance Index	:	99

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**Solaria Universal** Breathable
Number	:	54
Country	:	Italy
Product	:	paint
Colour	:	**brown**
Solar Reflectance%	:	67
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	51,4
Solar Reflectance Index	:	82

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**ECOBIOSUN** Washable
Number	:	55
Country	:	Italy
Product	:	paint
Colour	:	**green**
Solar Reflectance%	:	72
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	49,1
Solar Reflectance Index	:	88

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**ECOBIOSUN** Washable
Number	:	58
Country	:	Italy
Product	:	paint
Colour	:	**white**
Solar Reflectance%	:	80
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	44,9
Solar Reflectance Index	:	99

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**ECOBIOSUN** Washable
Number	:	56
Country	:	Italy
Product	:	paint
Colour	:	**yellow**
Solar Reflectance%	:	73
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	48,6
Solar Reflectance Index	:	89

ECOBIOS COOL ROOFING TECHNOLOGY

WWW.LEUC.IT

COOL ROOFS MATERIAL DATABASE

Name	:	**ECOBIOSUN** Washable
Number	:	65
Country	:	Italy
Product	:	paint
Colour	:	**red**
Solar Reflectance%	:	66
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	52,4
Solar Reflectance Index	:	79

ECOBIOS COOL ROOFING TECHNOLOGY

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COOL ROOFS MATERIAL DATABASE

Name	:	**ECOBIOSUN** Washable
Number	:	53
Country	:	Italy
Product	:	paint
Colour	:	**brown**
Solar Reflectance%	:	58
Infrared Emittance(-)	:	0,89
Temperature Rise (°C)	:	56,6
Solar Reflectance Index	:	68

ECOBIOS COOL ROOFING TECHNOLOGY COOL ROOFS Intelligent Energy Europe WWW.LEUC.IT	**COOL ROOFS MATERIAL DATABASE** Name : **Tixos Leùc** Breathable Number : 78 Country : Italy Product : thixotropic mortar Colour : **white** Solar Reflectance% : 85 Infrared Emittance(-) : 0,89 Temperature Rise (°C) : 42,0 Solar Reflectance Index : 107
ECOBIOS COOL ROOFING TECHNOLOGY COOL ROOFS Intelligent Energy Europe WWW.LEUC.IT	**COOL ROOFS MATERIAL DATABASE** Name : **Tixos CLIMA** Breathable Number : 79 Country : Italy Product : thixotropic mortar Colour : **white** Solar Reflectance% : 86 Infrared Emittance(-) : 0,89 Temperature Rise (°C) : 41,5 Solar Reflectance Index : 108

TECHNICAL COMMITTEE of the EU Cool Roofs Council
Assessment of International Standards for the Measurement and Determination of Solar and Thermal Properties

Supported by
Intelligent Energy Europe

1. SCOPE

The Technical Committee (TC) of the EU Cool Roofs Council was established in February 2009. Initially the TC aims to define acceptable procedures for measurement of the optical properties of materials employed in cool roof applications to and define a scheme for the implementation of cool roof technology which will facilitate the implementation of energy performance certification/accreditation procedures.

Principal areas of importance are:

- Identification of relevant physical properties affecting the performance of cool roofs
- Definition of criteria to be employed to quantify cool roof performance
- Measurement procedures and calculation methods complying with international standards
- Accreditation, certification and compliance

2. COOL ROOF RATING COUNCIL

The US Cool Roof Rating Council (CRRC) has a mature product rating programme which encompasses testing of material optical properties, colour, thickness and weathering; laboratory accreditation; criteria for product rating, licensing, CRRC label use, revocation, complaints, appeals and arbitration procedures.

The EU CRC confines itself initially to the determination of physical properties, compliance of necessary measurement and calculation procedures with European CEN standards and compatibility of European characterisation methods with US standards, e.g. ASTM.

3. DETERMINATION OF SOLAR REFLECTANCE, THERNAL EMITTANCE AND SOLAR REFLECTANCE INDEX OF ROOF COVERING MATERIALS

3.1. SOLAR REFLECTANCE INDEX

The Solar Reflectance Index (SRI) as defined in ASTM E-1980-01 (2) is a measure of the relative steady state temperature of the surface under standard solar and ambient conditions with respect to the standard white (SRI = 100, solar reflectance 0.80, thermal emittance 0.90) and standard black (SRI = 0, solar reflectance 0.05, thermal emittance 0.90).

The SRI may be calculated from

$$SRI = 123.97 - 141.35\chi + 9.655\chi^2$$

where

$$\chi = \frac{(\alpha - 0.029\varepsilon)(8.797 + h_c)}{9.5205\varepsilon \quad h_c}$$

and

α is the solar absorptance
ε is the thermal emittance
h_c is the convective coefficient in $W.m^{-2}.K^{-1}$.

The SRI is calculated for three convective coefficients, h_c, of 5, 12 and 30 $W.m^{-2}.K^{-1}$ corresponding to low, medium and high wind conditions respectively.

Evaluation guidelines for determination of solar reflectance, thermal emittance and solar reflective index have been published (3) in an ICC-ES Sustainable Attribute Verification and Evaluation Verification of Attributes Report (VAR). ASTM reference documents which support the necessary measurements and calculation procedures are cited. These standards are summarised in Table 1.

ASTM Reference	Title
ASTM C 1371-04a	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
ASTM C 1549-04	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflector
ASTM E 408-71 (2002)	Standard Test Method for Total Normal Emittance of Surfaces using Inspection-Meter Techniques
ASTM E 903-96	Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
ASTM E1918-97	Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field
ASTM E 1980-01	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces
ASTM G 7-97	Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials, ASTM International

Table 1. ASTM Reference Standards for determination of solar reflectance, thermal emittance and solar reflectance index of roof covering materials (3).

4. OPTICAL PROPERTIES STANDARDISATION IN EUROPE

In European CEN standards the property "solar reflectance index" appears not to be defined. Fully developed CEN standards for the measurement and calculation of ultraviolet, visible, solar optical properties and thermal radiative properties are widely used in e.g. the glass and glazing, blinds and shutters and surface finishing industries.

For CRRC applications and accreditation in the USA, determination of solar reflectance and thermal emittance has become dominated by measurements using portable reflectometers (see Table 1.). In contrast such properties for glazing and blind applications are normally determined using spectrophotometric techniques (4).

In Europe the use of portable reflectometer methods is not widespread save for their use in the measurement of colour. Integrated solar and thermal optical properties are normally determined from spectrophotometric measurements. Spectrophotometric measurements are more expensive but are known to give more information on surface properties and more accurate values of the respective optical properties (5).

4.1. MEASUREMENT PROCEDURES

Good practice procedures for the spectrophotometric measurement of the optical properties of materials are defined by CEN, CIE, ASHRAE and ASTM (6,7,8,9). These standards generally refer to the use of spectrophotometers with integrating sphere reflectance and transmittance accessories. From the spectral measurements integrated reflectance, transmittance and absorptance values are calculated to give ultraviolet, visible and solar properties.

For thermal properties, e.g. thermal emittance (emissivity) spectrometric methods are described in EN 12898 (10). A similar ASTM Standard exists (11) but was withdrawn in 2002.

A selection of the associated European calculation methods to determine optical properties from spectrophotmetric measurements is summarised below. Similar calculations are also defined in ISO 9050 (12).

4.2. CALCULATION METHODS

4.2.1. Visible Transmittance and Reflectance

The visible transmittance and reflectance of a sample is calculated using the relative spectral power distribution D of illuminant D_{65} (13) multiplied by the spectral sensitivity of the human eye V(λ) and the spectral bandwidth Δλ.

Measurements are made of the spectral transmittance, τ(λ), and the visible transmittance, τ_V, is then calculated using a weighted ordinate method (14): according to EN 410 using the relationship:

$$\tau_{\upsilon} = \frac{\int_{\lambda=380nm}^{780nm} D_{\lambda}\tau(\lambda)V(\lambda)d\lambda}{\int_{\lambda=380nm}^{780nm} D\,V(\lambda)d\lambda} \quad \frac{\sum_{\lambda=380nm}^{780nm} D_{\lambda}\tau(\lambda)V(\lambda)\Delta\lambda}{\sum_{380nm}^{780nm} D_{\lambda}V(\lambda)\Delta\lambda}$$

Measurements are made of the spectral reflectance ρ(λ), and the visible reflectance, ρ_V is also calculated by weighted ordinates according to EN 410 using the relationship:

$$\rho_v = \frac{\int_{\lambda=380nm}^{780nm} D_\lambda \rho(\lambda) V(\lambda) d\lambda}{\int_{\lambda=380nm}^{780nm} D_\lambda V(\lambda) d\lambda} = \frac{\sum_{\lambda=380nm}^{780nm} D_\lambda \rho(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda=380nm}^{780nm} D_\lambda V(\lambda) \Delta\lambda}$$

To evaluate these expressions the values of spectral transmittance and reflectance are taken at 10 nm intervals from 380 - 780 nm and the values are normalised since $\Sigma D_\lambda V(\lambda)\Delta\lambda = 1$. The normalised fractional contributions of each interval to the total sum are tabulated in EN 410 (14).

4.2.2. Solar transmittance and reflectance.

The solar transmittance, τ_s, is defined (15) as:

$$\tau_s = \frac{\int_{\lambda_1}^{\lambda_2} \tau_\lambda G_\lambda d\lambda}{\int_{\lambda_1}^{\lambda_2} G_\lambda d\lambda}$$

where G_λ is the spectral solar irradiation, τ_λ is the spectral transmittance and λ_1 and λ_2 respectively define the short and long wavelength limits of the solar spectral distribution.

The solar absorptance, α_s, and solar reflectance, ρ_s, are similarly defined:

$$\alpha_s = \frac{\int_{\lambda_1}^{\lambda_2} \alpha_\lambda G_\lambda d\lambda}{\int_{\lambda_1}^{\lambda_2} G_\lambda d\lambda}$$

$$\rho_s = \frac{\int_{\lambda_1}^{\lambda_2} \rho_\lambda G_\lambda d\lambda}{\int_{\lambda_1}^{\lambda_2} G_\lambda d\lambda}$$

where α_λ and ρ_λ are the spectral absorptance and spectral reflectance respectively.

It is normal only to measure ρ_λ and τ_λ and to deduce α_λ from the conservation relationship $\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$.

To evaluate the integrals the recommended procedure of EN 410 (9) is used and a weighted ordinate method is employed. Each of the integrals reduces to the form

$$\tau_s = \sum_{i=1}^{n} \tau_{\lambda i} f_i \qquad \rho_s = \sum_{i=1}^{n} \rho_{\lambda i} f_i \qquad \alpha_s = \sum_{i=1}^{n} \alpha_{\lambda i} f_i$$

where the family f_i are the relative proportions of the total solar energy in each equal wavelength interval and their sum is normalised to unity.

4.2.3. Thermal emittance

The spectral emittance, ε_λ, is derived from the relationship (15)

$$\varepsilon_\lambda = 1 - (\rho_\lambda + \tau_\lambda)$$

For an opaque sample, where $\tau_\lambda = 0$, this relationship reduces to $\varepsilon_\lambda = 1 - \rho_\lambda$
The spectral emittance, ε , derived from spectral reflectance measurements is convoluted with the Planck blackbody spectral distribution, $E_{b\lambda}$, for a temperature of 283 K and normalised to the ideal emitter (= 1) to give the total near-normal hemispherical thermal emittance ε_n .

The thermal emittance is thus expressed as

$$\varepsilon_n = \frac{\int_{\lambda_1'}^{\lambda_2'} \varepsilon_\lambda E_{b\lambda} \, d\lambda}{\int_{1}'^{\lambda_2'} E_{b\lambda} \, d\lambda}$$

where $_1'$ and λ_2' are the respective wavelength limits of the blackbody spectral distribution for the temperature of interest.

To evaluate this expression, the selected ordinate method prescribed in EN 673 and EN 12898 was used (10, 16).

5. ENERGY PERFORMANCE CERTIFICATION

Energy performance certification in European buildings is driven by the Energy Performance in Buildings Directive (EPBD) (17). The EPBD identifies an energy saving potential of 22% and certification of building energy performance and carbon savings are determined using Member States developed methodologies. Results are expressed on a bar scale Classes A-G, where Class A is a building with the lowest energy consumption. The harmonisation and compatibility of European CEN standards employed in support of the EPBD is being analysed in the EIE CENSE project and can be followed at the European EPBD Building Technology Platform (18). Relevant and related CEN standards for implementation of EPBD are listed in Appendix 1. An ASHRAE review of methods for determining solar optical properties of building envelope materials is reproduced as Appendix 2.

The route to EU product certification for components of the building envelope, e.g. windows, shutters, blinds, roofs, cool roofs, now appears as a high priority to underpin EPBD implementation and to facilitate the marketing of energy efficient products.

For glazing, blinds and shutters, windows and complex glazing (window + blind), energy performance values are calculated from the integrated visible, solar and thermal properties. Normally the total solar energy transmittance, g, and the thermal transmittance (U-value) are calculated. These values can be used to determine the energy balance on the building component and can be used as input parameters to building energy analysis tools to enable simulation of energy performance and associated energy and environmental impacts and benefits. A similar route is being taken in North America for the new Window 6 design tool which is capable of handling complex glazing and feeding its outputs to its associated energy simulation software, RESFEN and COMFEN, for calculation of energy performance in residential and commercial buildings respectively (19).

Cool roofs are intended to contribute to the reduction of cooling loads in buildings by rejecting solar gain through high solar reflectance and enhancing radiative loss to the environment and the sky through high thermal emittance. The challenge for the EU Cool Roof Council is to determine whether knowledge of a compound surface property, i.e. the solar reflectance index, can be quantitatively related to a reduction in cooling demand of the building. If this can be determined the possibility for energy performance certification of a cool roof is enhanced. If the SRI alone is not a reliable indicator then alternative or more extensive characterisation of roof performance will be necessary.

6. REFERENCES

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17. Energy Performance of Buildings, European Union Directive 2002/91/EC, Official Journal of the European Communities L1/65, 4.1.2003.

18. CENSE, Intelligent Energy Europe, Coordinator TNO, The Netherlands.

19. WINDOW (http://windows.lbl.gov/materials/IGDB/), Lawrence Berkeley National Laboratory, USA.

APPENDIX 1 CEN Standards relevant for implementation of EPBD

EN 410,	Glass in Building: Determination of Luminous and Solar Characteristics of Glazing, 1998.
EN 673	Determination of Thermal Transmittance, CEN TC/129, 1997.
EN 674	Glass in building – Determination of thermal transmittance (U value – Guarded hot plate method.
EN 675	Glass in building – Determination of thermal transmittance (U value – Heat flow meter method.
EN 1098	Glass in building – Determination of thermal transmittance (U value – Calibrated and guarded hot plate method.
EN 12898	Glass in Building – Determination of the Emissivity, 1998
EN 13363-1,	Solar Protection Devices combined with Glazing – Calculation of Solar and Light Transmittance – Part 1, Simplified Calculation Method, 2003.
EN 13363-2	Solar Protection Devices combined with Glazing – Calculation of Solar and Light Transmittance – Part 2, Detailed Calculation Method, 2005.
ISO 10077-1	Thermal performance of windows, doors and shutters – Calculation of thermal transmittance Part 1 : General, 2006.
prEN 10077-2	Thermal performance of windows, doors and shutters – Calculation of thermal transmittance Part 2 : Numerical method for frames.
ISO 15099	Thermal performance of windows, doors and shading device – detailed calculations, 1999.
ISO 9050,	Glass in Building: Determination of Light Transmittance, Solar Direct Factors, 1990.
EN 12464-1	Light and lighting – Lighting of work places- Part 1: Indoor workplaces
EN 12599	Ventilation for buildings – Test procedures and measuring methods for handing over installed ventilation and air conditioning systems
EN 12792 2003	Ventilation for buildings - Symbols, terminology and graphical symbols
EN 12831	Heating systems in buildings - Method for calculation of the design heat load
EN 13779	Ventilation for non-residential buildings – Performance requirements for ventilation and room-conditioning systems
prEN 14500	Blinds and shutters – Thermal and visual comfort – Test and calculation methods
prEN 15193	Energy performance of buildings - Energy requirements for lighting
prEN 15203	Energy performance of buildings — Assessment of energy use and definition of energy ratings
prEN 15217	Energy performance of buildings — Methods for expressing energy performance and for energy certification of buildings
prEN 15239	Ventilation for buildings - Energy performance of buildings -Guidelines for inspection of ventilation systems
prEN 15240	Ventilation for buildings - Energy performance of buildings -Guidelines for inspection of air-conditioning systems

prEN 15241	Ventilation for buildings - Calculation methods for energy losses due to ventilation and infiltration in commercial buildings
prEN 15242	Ventilation for buildings — Calculation methods for the determination of air flow rates in buildings including infiltration
prEN 15243	Ventilation for buildings — Calculation of room temperatures and of load and energy for buildings with room conditioning systems
prEN 15251	Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
prEN 15255	Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures
prEN 15265	Thermal performance of buildings - Calculation of energy use for space heating and cooling - General criteria and validation procedures
prEN 15378	Heating systems in buildings - Inspection of boilers and heating systems
EN ISO 7726	Ergonomics of the thermal environment - Instruments for measuring physical quantities (ISO 7726:1998)
EN ISO 7730	Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria (ISO
EN ISO 8996	Ergonomics of the thermal environment - Determination of metabolic rate (ISO 8996:2004)
EN ISO 9920	Ergonomics of the thermal environment - Estimation of the thermal insulation and evaporative resistance of a clothing ensemble (ISO 9920:1995)
EN ISO 13731	Ergonomics of the thermal environment - Vocabulary and symbols (ISO 13731:2001)
EN ISO 13790	Thermal performance of buildings - Calculation of energy use for space heating (ISO 13790:2004)
EN ISO 13791	Thermal performance of buildings - Calculation of internal temperatures of a room in summer without mechanical cooling - General criteria and validation procedures (ISO 13791:2004)
EN ISO 13792	Thermal performance of buildings - Calculation of internal temperatures of a room in summer without mechanical cooling -Simplified methods (ISO 13792:2005)
ISO/TS 14415	Ergonomics of the thermal environment - Application of International Standards to people with special requirements
ISO/DIS 16814	Building environment design - Indoor air quality - Methods of expressing the quality of indoor air for human occupancy

Table 1: Standards Dealing with Solar Measurements

Measurement	Standard	Description
General Reflectance	ASTM C 1549	*Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer*
	ASTM E 424	*Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials*
	ASTM E 429	*Standard Test Method for Measurement and Calculation of Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments* (Withdrawn 1996)
	ASTM E 903	*Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres* (Withdrawn 2005)
	ASTM E 1175	*Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*
	DIN 5036	*Radiometric and photometric properties of materials*
Bi-directional Reflectance	ASTM E 167	*Standard Practice for Goniophotometry of Objects and Materials* (Withdrawn 2005)
Directional Reflectance	ASTM E 1392	*Standard Practice for Angle Resolved Optical Scatter Measurements on Specular or Diffuse Surfaces* (Withdrawn 2003)
Specular Reflectance	ASTM F 768	*Standard Method for Specular Reflectance and Transmittance Measurements of Optically Flat-Coated and Non-Coated Specimens* (Withdrawn 1994)
General Transmittance	ASTM E 424	*Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials*
	ASTM E 903	*Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres* (Withdrawn 2005)
	ASTM E 1084:	*Standard Test Method for Solar Transmittance (Terrestrial) of Sheet Materials Using Sunlight*
	ASTM E 1175	*Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*
	DIN 5036	*Radiometric and photometric properties of materials*
	DIN 67507:	*Light transmittance, radiant transmittance and total energy transmittance of glazings*
	EN 13363-1 2003:	*Solar protection devices combined with glazing - Calculation of solar and light transmittance - Part 1 : Simplified method*
	ISO 9050 2003:	*Glass in building -- Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors*
Bi-directional Transmittance	ASTM E 167	*Standard Practice for Goniophotometry of Objects and Materials* (Withdrawn 2005)
	ASTM E 1348:	*Standard Test Method for Transmittance and Color by Spectrophotometry Using Bidirectional Geometry*
Specular Reflectance	ASTM F 768	*Standard Method for Specular Reflectance and Transmittance Measurements of Optically Flat-Coated and Non-Coated Specimens* (Withdrawn 1994)

Table 2: Standards Dealing with Photometric Measurements

Measurement	Standard	Description
Reflectance	ASTM E 971	*Standard Practice for Calculation of Photometric Transmittance and Reflectance of Materials to Solar Radiation*
	ASTM E 167	*Standard Practice for Goniophotometry of Objects and Materials* (Withdrawn 2005)
	ASTM E 1175	*Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*
	CIE 130-1998	*:Practical methods for the measurement of reflectance and transmittance*
	DIN 5036	*Radiometric and photometric properties of materials*
Transmittance	ASTM D 1003:	*Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*
	ASTM E 971	*Standard Practice for Calculation of Photometric Transmittance and Reflectance of Materials to Solar Radiation*
	ASTM E 972	*Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight*
	ASTM E 167	*Standard Practice for Goniophotometry of Objects and Materials* (Withdrawn 2005)
	ASTM E 1175	*Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*
	CIE 130-1998	*:Practical methods for the measurement of reflectance and transmittance*
	DIN 5036	*Radiometric and photometric properties of materials*

Table 3: Standards Dealing with Longwave Measurements

Measurement	Standard	Description
Emissivity	ASTM E408-71 (R1996)	*Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques.*
	ASTM E 1585	*Standard Test Method for Measuring and Calculating Emittance of Architectural Flat Glass Products Using Spectrometric Measurements* (Withdrawn 2002)

Table 4: Miscellaneous Topics

Standard	Description
ASTM E1980-01	*Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces.*
ASTM G 159	*Standard Tables for References Solar Spectral Irradiances: Direct Normal and Hemispherical for a 37^o Tilted Surface*
ASTM E 891	*Tables for Terrestrial Direct Normal Solar Spectral Irradiance Tables for Air Mass 1.5* (Withdrawn 1999)
ASTM E 892:	*Tables for Terrestrial Solar Spectral Irradiance at Air Mass 1.5 for a 37-Deg Tilted Surface* (Withdrawn 1999)
ISO 9845-1 1992	*Solar energy -- Reference solar spectral irradiance at the ground at different receiving conditions -- Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

ASTM Standards

ASTM C 1549: *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 temperatures and heat flows across surfaces exposed to solar radiation.
>
> This test method does not supplant Test Method E 903 which measures solar reflectance over the wavelength range 250 to 2500 nm using integrating spheres. The portable solar reflectometer is calibrated using specimens of known solar reflectance to determine solar reflectance from measurements at four wavelengths in the solar spectrum: 380 nm, 500 nm, 650 nm, and 1220 nm. This technique is supported by comparison of reflectometer measurements with measurements obtained using Test Method E 903. This test method is applicable to specimens of materials having both specular and diffuse optical properties. It is particularly suited to the measurement of the solar reflectance of opaque materials.

ASTM D 1003: *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*

> This test method covers the evaluation of specific light-transmitting and wide-angle-light-scattering properties of planar sections of materials such as essentially transparent plastic. A procedure is provided for the measurement of luminous transmittance and haze. Material having a haze value greater than 30% is considered diffusing and should be tested in accordance with Practice E167.

ASTM E 167 (Withdrawn 2005): *Standard Practice for Goniophotometry of Objects and Materials*

ASTM E 408-71(R1996): *Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques.*

ASTM E 424: *Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials*

> These test methods cover the measurement of solar energy transmittance and reflectance (terrestrial) of materials in sheet form. Method A, using a spectrophotometer, is applicable for both transmittance and reflectance and is the referee method. Method B is applicable only for measurement of transmittance using a pyranometer in an enclosure and the sun as the energy source. Specimens for Method A are limited in size by the geometry of the spectrophotometer while Method B requires a specimen 0.61 m (2 ft). For the materials studied by the drafting task group, both test methods give essentially equivalent results.

ASTM E 429 (Withdrawn 1996): *Standard Test Method for Measurement and*

Calculation of Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments

ASTM E 891 (Withdrawn 1999): *Tables for Terrestrial Direct Normal Solar Spectral Irradiance Tables for Air Mass 1.5*

ASTM E 892 (Withdrawn 1999): *Tables for Terrestrial Solar Spectral Irradiance at Air Mass 1.5 for a 37-Deg Tilted Surface*

ASTM E 903 (Withdrawn 2005): *Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres*

ASTM E 971: *Standard Practice for Calculation of Photometric Transmittance and Reflectance of Materials to Solar Radiation*

> This practice describes the calculation of luminous (photometric) transmittance and reflectance of materials from spectral radiant transmittance and reflectance data obtained from Test Method E 903.
>
> Determination of luminous transmittance by this practice is preferred over measurement of photometric transmittance by methods using the sun as a source and a photometer as detector except for transmitting sheet materials that are inhomogeneous, patterned, or corrugated.

ASTM E 972: *Standard Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight*

> This test method covers the measurement of solar photometric transmittance of materials in sheet form. Solar photometric transmittance is measured using a photometer (illuminance meter) in an enclosure with the sun and sky as the source of radiation. The enclosure and method of test is specified in Test Method E 1175 (or Test Method E 1084).
>
> The purpose of this test method is to specify a photometric sensor to be used with the procedure for measuring the solar photometric transmittance of sheet materials containing inhomogeneities in their optical properties.

ASTM E 1084: *Standard Test Method for Solar Transmittance (Terrestrial) of Sheet Materials Using Sunlight*

> This test method covers the measurement of solar transmittance (terrestrial) of materials in sheet form by using a pyranometer, an enclosure, and the sun as the energy source.
>
> This test method also allows measurement of solar transmittance at angles other than normal incidence.
>
> This test method is applicable to sheet materials that are transparent, translucent, textured, or patterned.

ASTM E 1175: *Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere*

> This test method covers the measurement of the absolute total solar or

photopic reflectance, transmittance, or absorptance of materials and surfaces. Although there are several applicable test methods employed for determining the optical properties of materials, they are generally useful only for flat, homogeneous, isotropic specimens. Materials that are patterned, textured, corrugated, or are of unusual size cannot be measured accurately using conventional spectrophotometric techniques, or require numerous measurements to obtain a relevant optical value. The purpose of this test method is to provide a means for making accurate optical property measurements of spatially nonuniform materials.

This test method is applicable to large specimens of materials having both specular and diffuse optical properties. It is particularly suited to the measurement of the reflectance of opaque materials and the reflectance and transmittance of semitransparent materials including corrugated fiber-reinforced plastic, composite transparent and translucent samples, heavily textured surfaces, and nonhomogeneous materials such as woven wood, window blinds, draperies, etc.

ASTM E 1348: *Standard Test Method for Transmittance and Color by Spectrophotometry Using Bidirectional Geometry*

This test method describes the instrumental measurement of the reflection properties and color of object-color specimens by use of a spectrophotometer or spectrocolorimeter with a bidirectional optical measuring system, such as annular, circumferential, or uniplanar 45/0 or 0/45 geometry.

This test method is generally suitable for any flat object-color specimen. It is especially recommended for measuring retroreflective specimens, fluorescent specimens, and specimens of intermediate gloss.

ASTM E 1392 (Withdrawn 2003): *Standard Practice for Angle Resolved Optical Scatter Measurements on Specular or Diffuse Surfaces*

ASTM E1980-01: *Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces.*

ASTM E 1585 (Withdrawn 2002): *Standard Test Method for Measuring and Calculating Emittance of Architectural Flat Glass Products Using Spectrometric Measurements*

ASTM F 768 (Withdrawn 1994): *Standard Method for Specular Reflectance and Transmittance Measurements of Optically Flat-Coated and Non-Coated Specimens*

ASTM G 159: *Standard Tables for References Solar Spectral Irradiances: Direct Normal and Hemispherical for a 37° Tilted Surface*

These tables contain terrestrial solar spectral irradiance distributions for use in terrestrial applications that require a standard reference spectral irradiance for hemispherical solar irradiance (consisting of both direct and diffuse components) incident on a sun-facing, 37° tilted surface or the direct normal spectral irradiance. The data contained in these tables reflect reference spectra with uniform wavelength interval (0.5 nanometer (nm) below 400 nm, 1 nm between 400 and 1700 nm, an intermediate wavelength at 1702 nm, and 5 nm intervals from 1705 to 4000 nm). The data tables represent reasonable cloudless atmospheric conditions favorable for photovoltaic (PV) energy production, as well as weathering and durability exposure applications.

ISO Standards

ISO 9050:2003: *Glass in building -- Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors*

ISO 9050:2003 specifies methods of determining light and energy transmittance of solar radiation for glazing in buildings. These characteristic data can serve as a basis for light, heating and ventilation calculations of rooms and can permit comparison between different types of glazing.

ISO 9050:2003 is applicable both to conventional glazing units and to absorbing or reflecting solar-control glazing, used as glazed apertures. The appropriate formulae for single, double and triple glazing are given. Furthermore, the general calculation procedures for units consisting of more than components are established.

ISO 9050:2003 is applicable to all transparent materials. One exception is the treatment of the secondary heat transfer factor and the total solar energy factor for those materials that show significant transmittance in the wavelength region of ambient temperature radiation (5 microns to 50 microns), such as certain plastic sheets.

ISO 9845-1:1992: *Solar energy -- Reference solar spectral irradiance at the ground at different receiving conditions -- Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

Provides an appropriate standard spectral irradiance distribution to be used in determining relative performance of solar thermal, photovoltaic, and other system components and materials where the direct and hemispherical irradiance component is desired. The tables presented define an air mass 1,5 solar spectral irradiance for the direct normal radiation - 5,8° field-of-view angle - and hemispherical radiation on an equator-facing, 37° tilted plane for an albedo of 0,2. These tables are intended to represent ideal clear sky conditions.

DIN / CEN Standards

EN 13363-1:2003: *Solar protection devices combined with glazing - Calculation of solar and light transmittance - Part 1 : Simplified method*

This European Standard specifies a simplified method based on the thermal transmittance and total solar energy transmittance of the glazing and on the light transmittance and reflectance of the solar protection device to estimate the total solar energy transmittance of a solar protection device combined with glazing.

The method applies to all types of solar protection devices parallel to the glazing such as louver, venetian or roller blinds. The position of the solar protection device can be interior, exterior or between single panes in a dual glazing system. It is applicable when the total solar energy transmittance of the glazing is between 0,15 and 0,85. Venetian or louver blinds are assumed to be adjusted so that there is no direct solar penetration. It is assumed that for external solar protection devices and for integrated solar protection devices, the space between the solar protection devices and the glazing is unventilated and for internal solar protection devices this space is ventilated.

The resulting g-values of the simplified method given here are approximate and their deviation from the exact values lie within the range between +0,10 and -0,02. The results generally tend to lie on the safe side for cooling load estimations. The results are not intended to be used for calculating beneficial solar gains or thermal comfort criteria.

The simplified method is based on the normal incidence of radiation and does not take into account either the angular dependence of transmittance and the reflectance or the differences of spectral distribution. An allowance can be made for this fact when applying the method. For cases not covered by the method given in this standard more exact calculations based on the optical properties (in general the spectral data) of glass and solar protection device can be carried out in accordance with EN 13363- 21, Solar protection devices combined with glazing – Calculation of solar and light transmittance – Part 2: Reference method.

DIN 5036: *Radiometric and photometric properties of materials Part 1: Definitions / Part 3: Methods of Measurement / Part 4: Classification*

DIN 67507: *Light transmittance, radiant transmittance and total energy transmittance of glazings*

CIE Standards

CIE 130-1998:*Practical methods for the measurement of reflectance and transmittance*

The characteristics of materials related to their reflection and transmission properties are defined in accordance with the International Lighting Vocabulary and other relevant CIE publications. The parameters affecting these characteristics and the principles of measurement involved, which are the same whether the measurement is made in terms of spectral or weighted (e.g. luminous) characteristics, are specified. Methods, using an integrating sphere, are recommended for the measurement of: reflectance for directional and hemispherical incidence of radiation, diffuse reflectance, transmittance for directional and hemispherical incidence of radiation, diffuse transmittance.

Specific methods are also recommended for the measurement of: regular reflectance, regular transmittance, radiance/luminance factor (radiance/luminance coefficient q).