The Cool Roofs Project

Mat Santamouris

We face an important change of the climate.

Ambient temperatures increase.

Heat waves are more frequent.

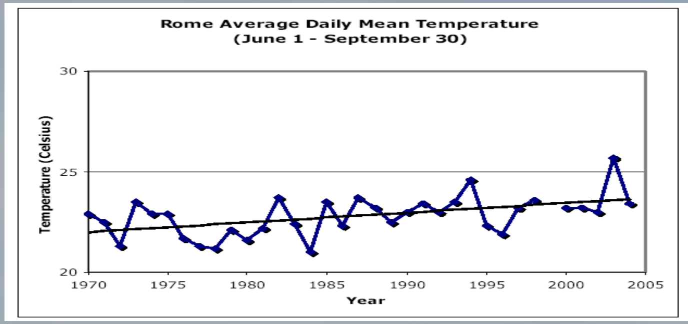
Hot spells have a longer duration.

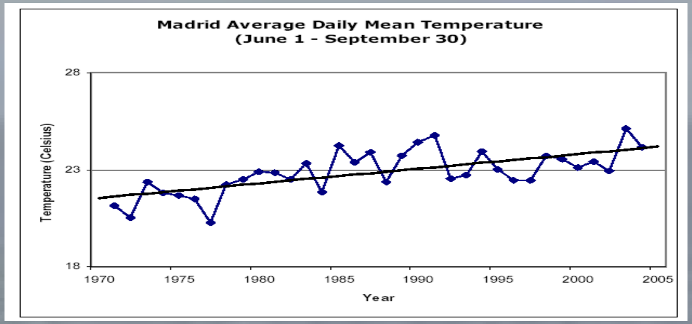
Poor design and uncontrolled development of urban areas increase the heat island intensity.

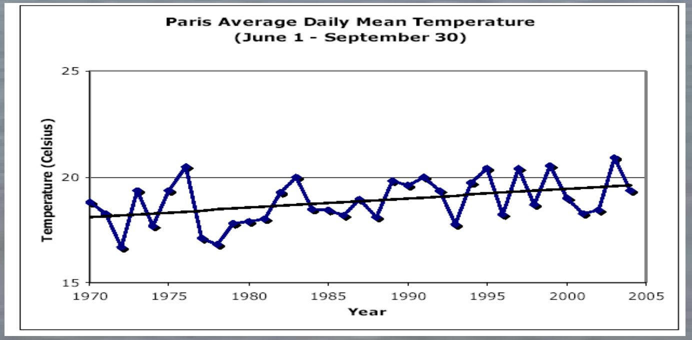
Human beings are more vulnerable and have to respond.

Many climatological studies have shown an important increase of the average mean daily ambient temperature in most southern European cities, like Paris, Madrid, Rome and Lisbon.

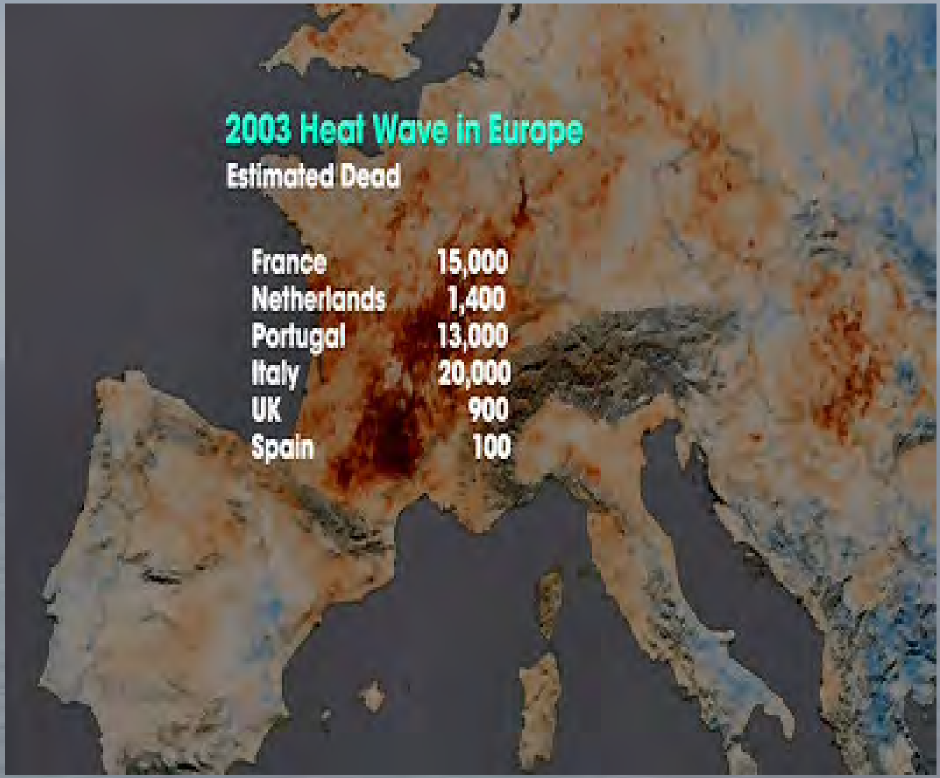
Temperature increase is between 2-3 Degrees. Also, an important increase of the cooling degree days has been recorded.





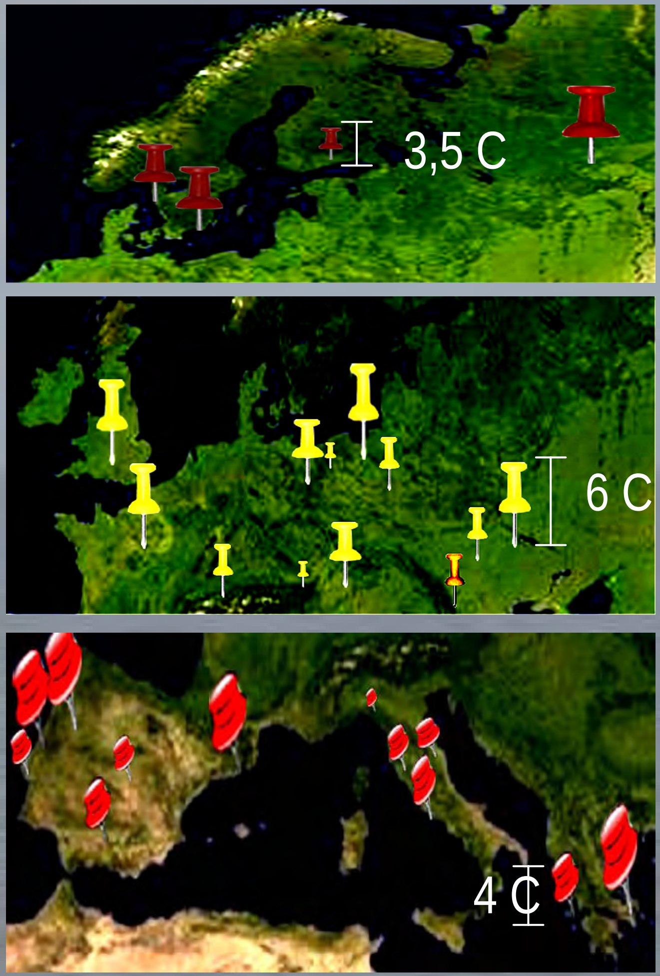


Heat Waves in Europe are more frequent. High temperatures increase the vulnerability of citizens and in particular of low income people. Studies in Europe, have shown that the greatest excess in mortality was registered in those with low socioeconomic status leaving in buildings with improper heat protection and ventilation.

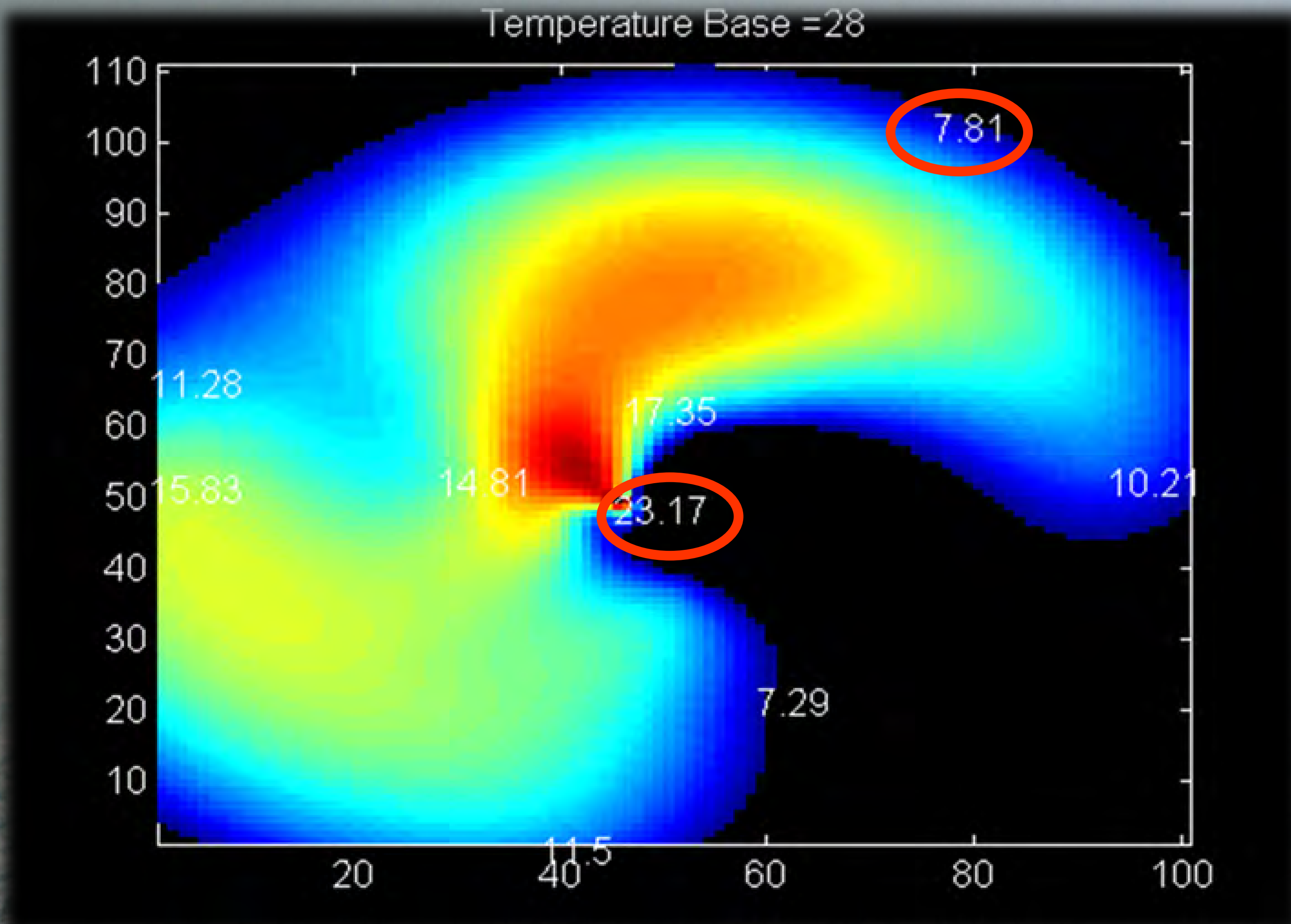


The Proof

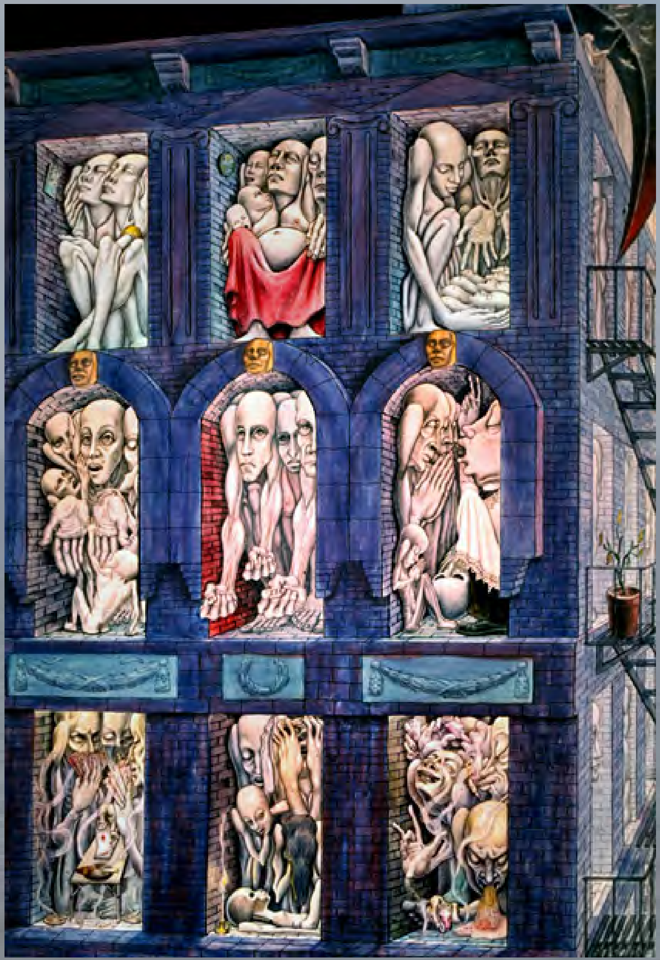
Heat Island intensity ranges between 1-10 C.
Heat Island is present in low, mid and high latitude locations.
It is observed during the day and the night period.
Especially in the south , heat island is very important during the day period contributing to a high increase of discomfort hours, increase of the cooling load of buildings and a very high increase of the peak electricity demand.



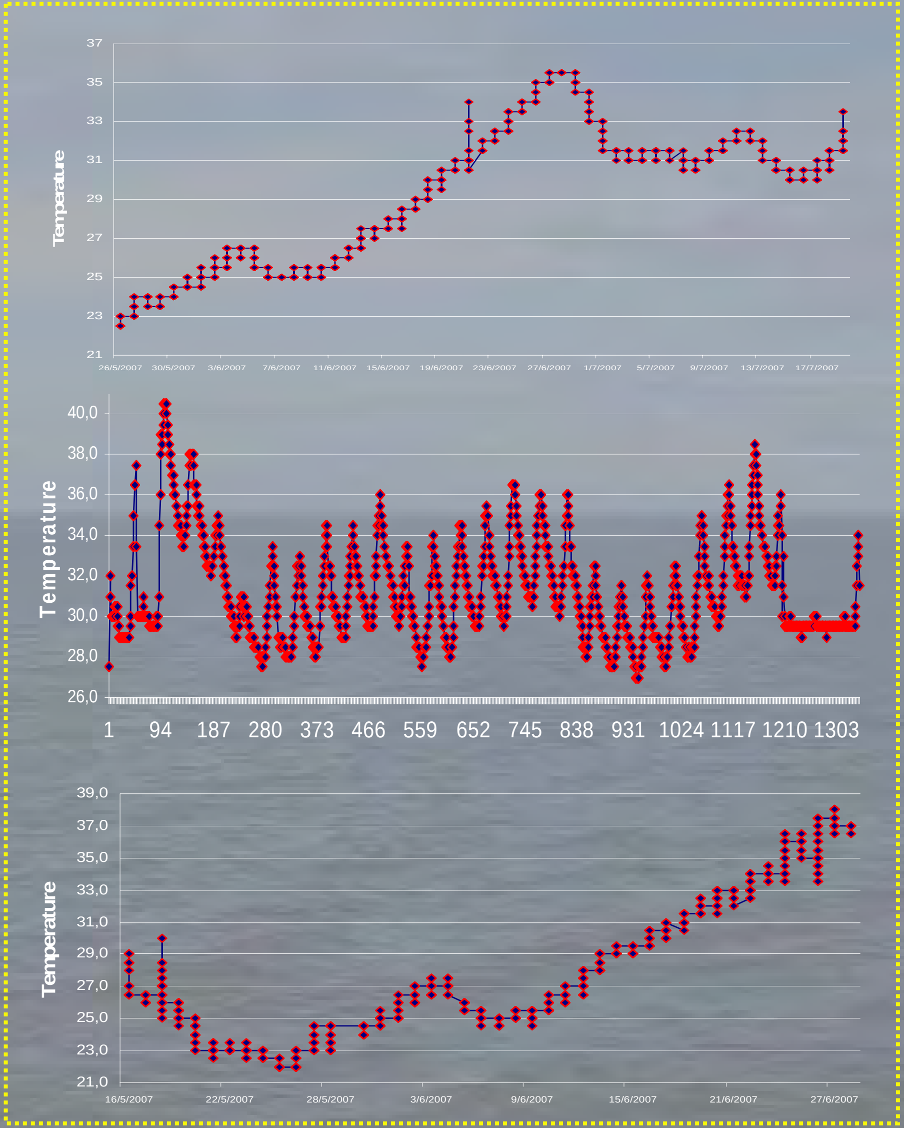
The Impact


Temperature Base =28
110
100
90
80
70
60
50
40
30
20
10
20
40
60
80
100
7.81
11.28
17.35
15.83
14.81
23.17
10.21
7.29
11.5

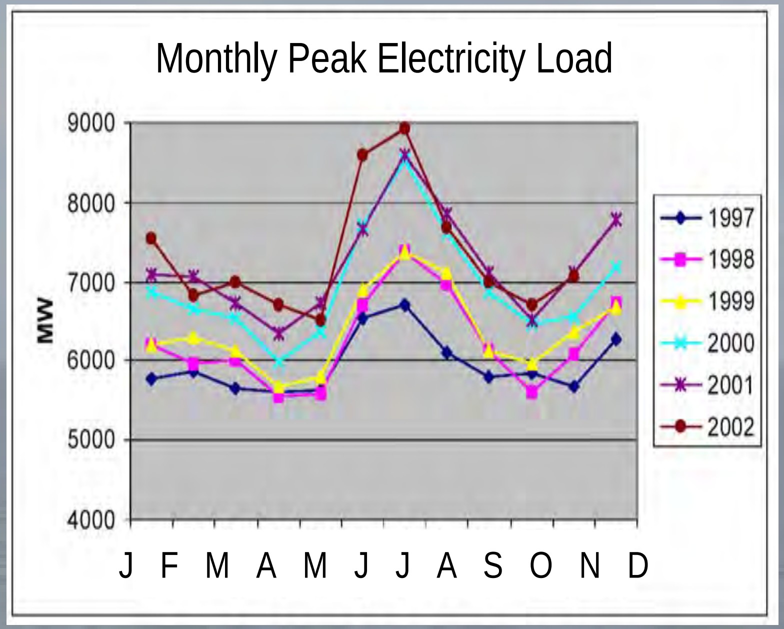
Low income population in both the developed and under development world is living in non appropriate shelters and is vulnerable to high ambient temperatures and extreme heat phenomena.
According to the United Nations more than one billion of urban citizens, live in non appropriate houses while in most cities of less developed countries, about one to two thirds of the population live in poor quality and overcrowded housing, without electricity and energy networks and are under the risk of environmental phenomena



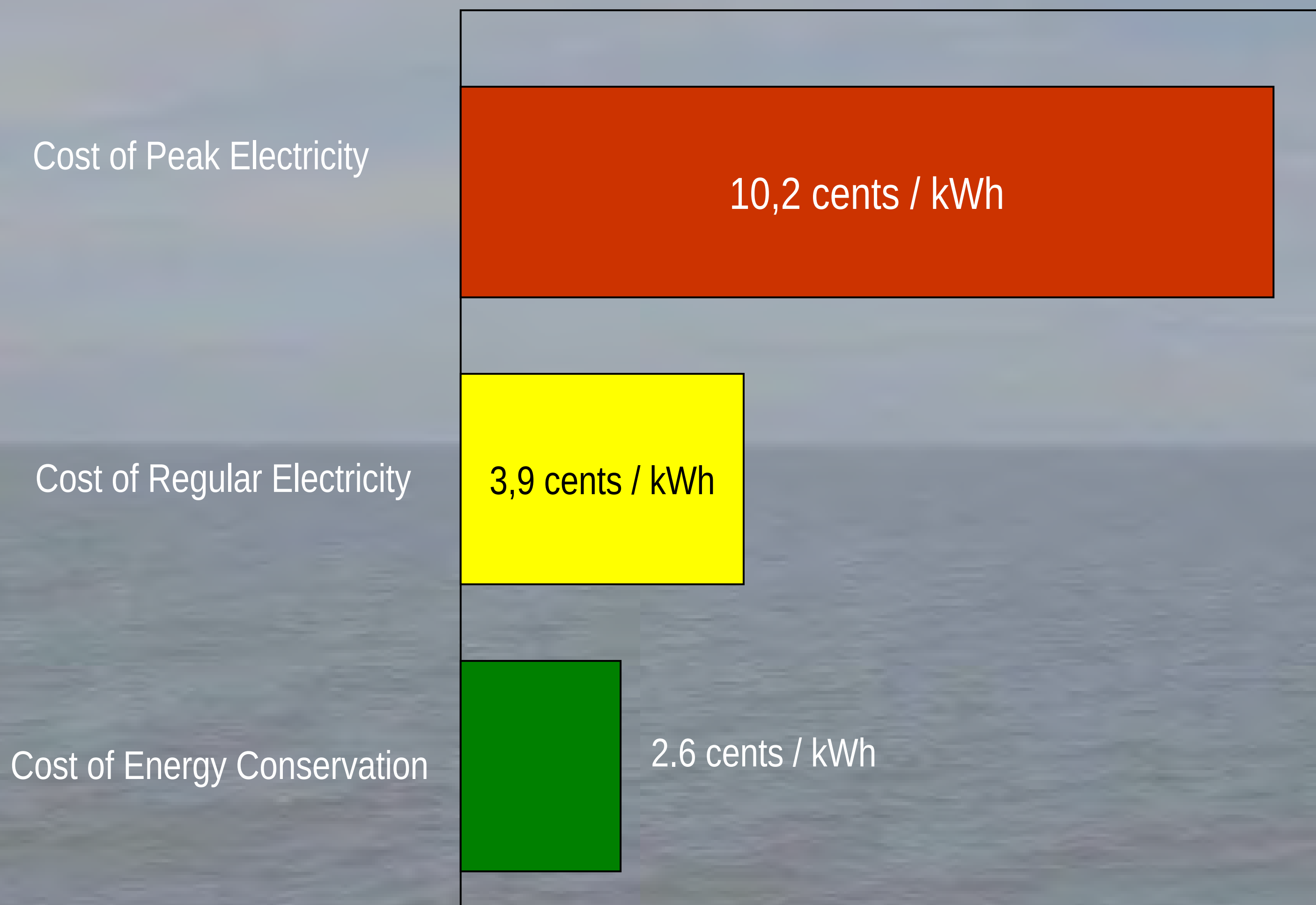
Measurements of indoor temperatures in almost 60 low income houses without air conditioning, insulation and double glazing, have been performed in Athens, during the whole summer of 2007. For almost 50 % of the measurement period, indoor temperatures where higher than 34 C, presenting maximum close to 40 C. Hot spells of more than 38 hours above 30 C have been recorded.



The use of air conditioning increases the peak electricity demand in most of the Southern European countries.
In parallel, this is the main reason of blackouts and electricity shortages.
Such a huge increase of the peak electricity demand oblige utilities to built additional power plants operating under a low utilisability factor, and thus, increase the cost of electricity



The Impact


Cost of Peak Electricity
10,2 cents / kWh
Cost of Regular Electricity
3,9 cents / kWh
Cost of Energy Conservation
2.6 cents / kWh

The Impact

Huge Increase of CO2 because of A/C

Unit: tonnes CO2	1990	1996	2010	2020
Austria	157	1 603	15 748	31 467
France	26 860	87 377	285 231	468 957
Germany	7 845	25 615	139 241	265 983
Greece	99 235	959 939	2 387 187	3 737 087
Italy	182 591	2 247 038	2 923 568	3 623 486
Portugal	147 358	358 099	1 038 841	1 519 546
Spain	n.a. (around 90 000)	1 124 255	4 381 826	7 130 489
UK	47 710	219 640	704 204	1 165 583
Other E.U	4 694	15 369	83 545	159 590
Total E.U	516 451 (606 451)	5 038 935	11 959 391	18 102 187

The Ideas

Addressing successful solutions to reduce energy and environmental effects of air conditioning is a strong requirement for the future.

Possible solutions include:

1. Improvement of the urban microclimate to fight the effect of heat island and temperature rise and the corresponding increase of the cooling demand in buildings
2. Use of appropriate technology to improve indoor comfort conditions and reduce cooling needs

Techniques to Improve the Urban Microclimate and Heat Island Mitigation strategies concentrate on :

- the increased use of green areas,

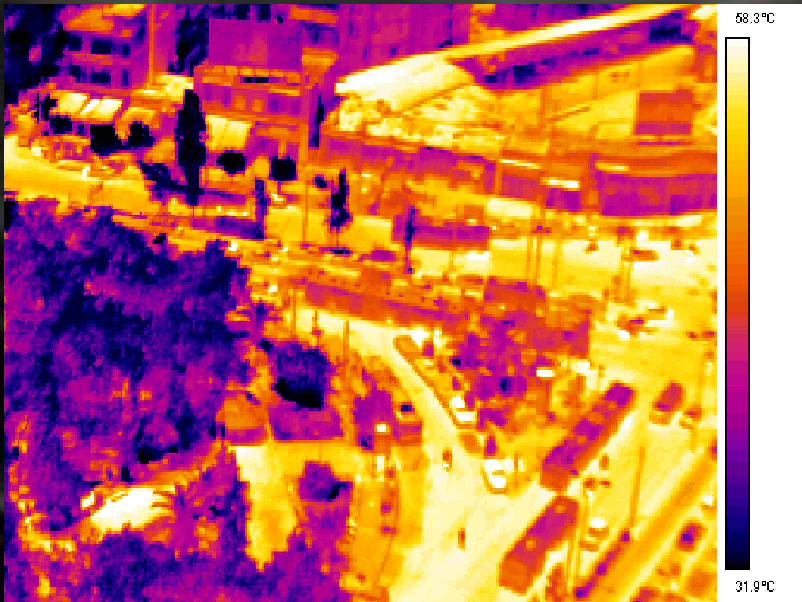
-the use of appropriate materials, in particular of white and colored high reflective coatings,

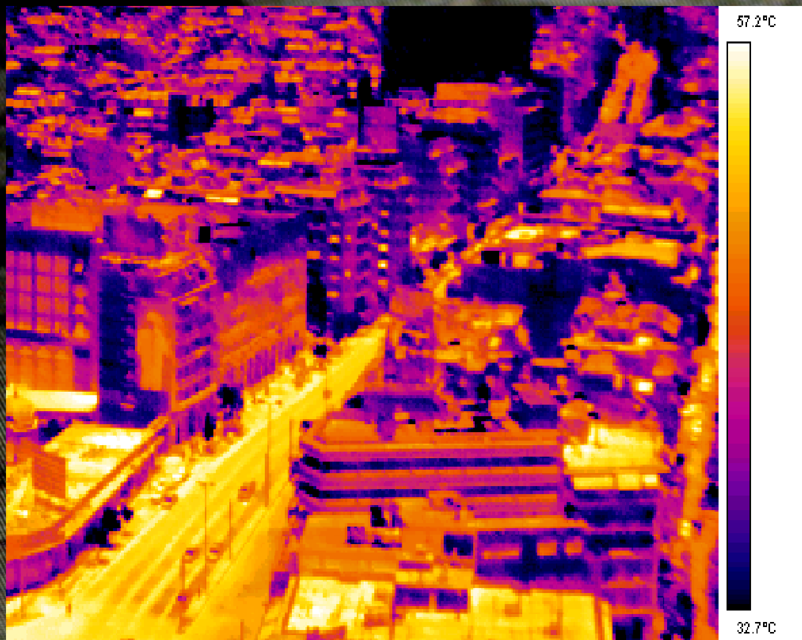
- decrease of anthropogenic heat

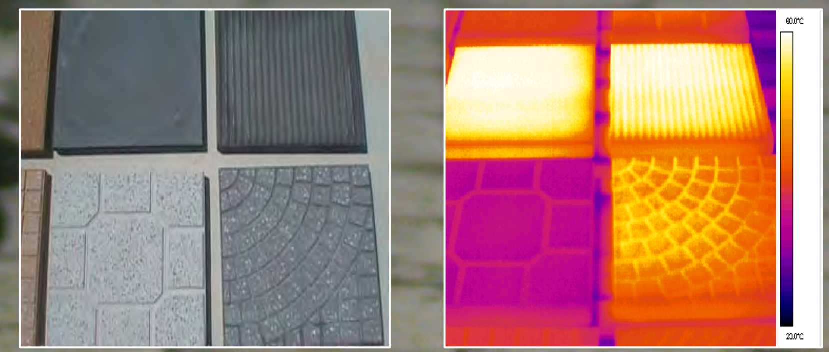
- use of cool sinks for heat dissipation,

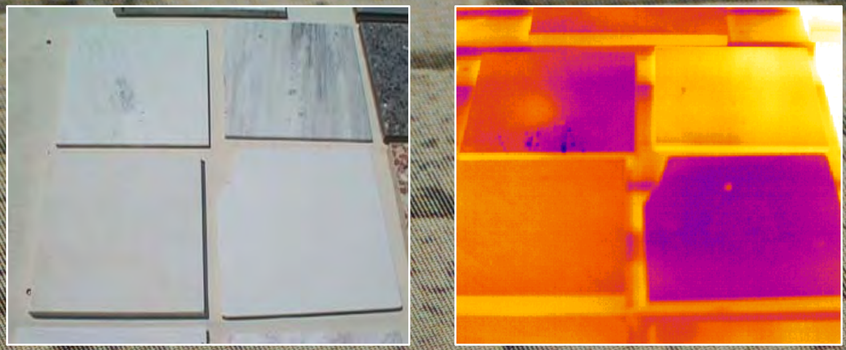
- appropriate layout of urban canopies involving the use of solar control, techniques to enhance air flow, etc.

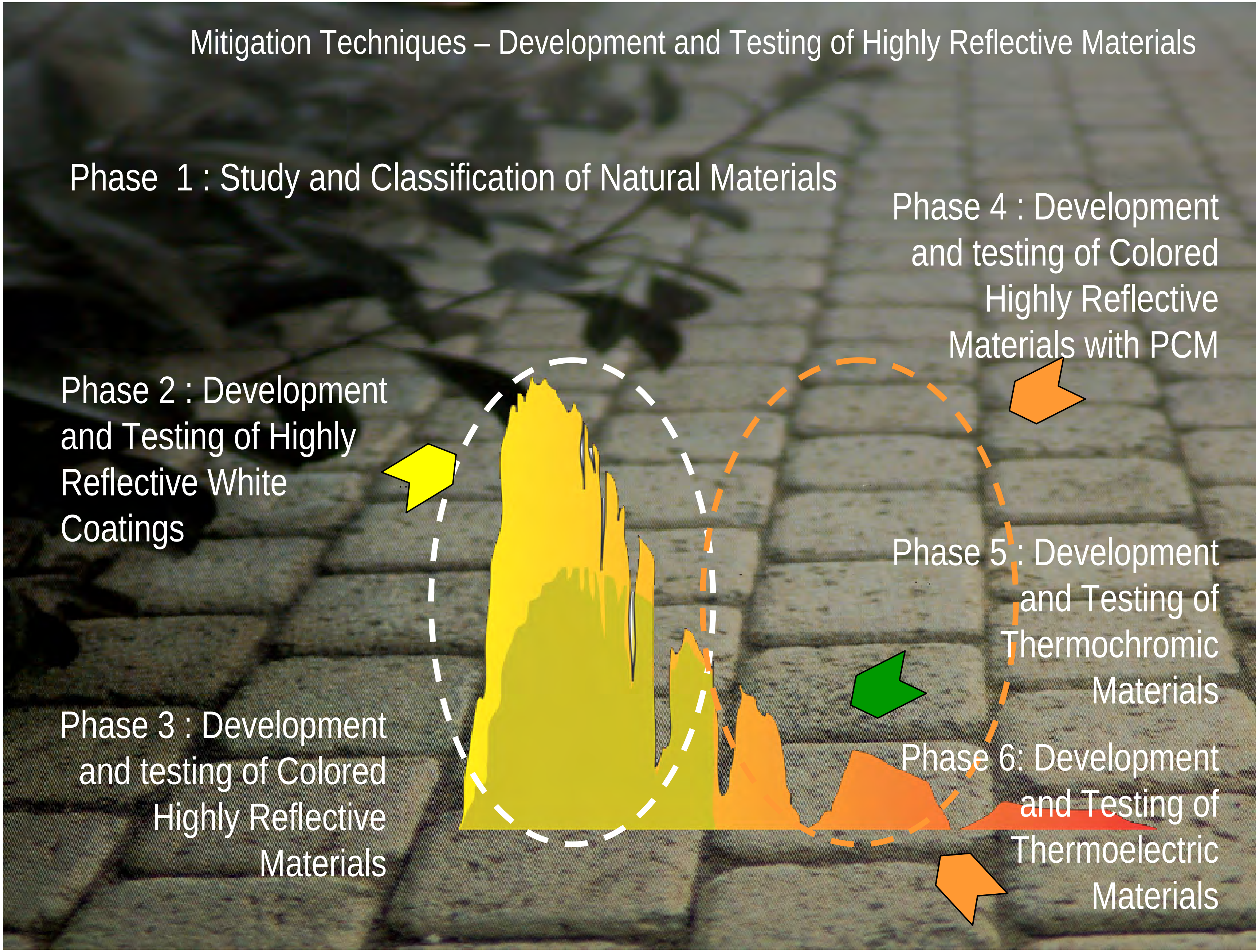
The Role of Materials







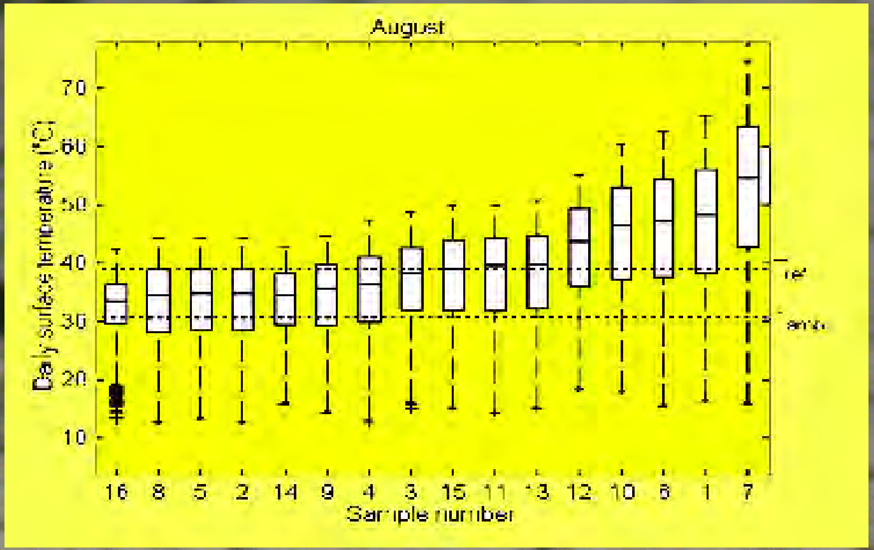


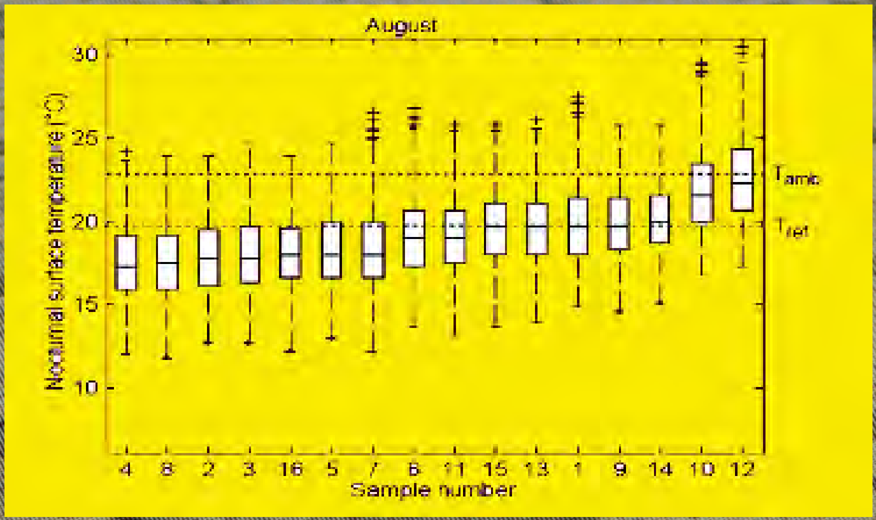

Mitigation Techniques – Development and Testing of Highly Reflective Materials
Phase 1 : Study and Classification of Natural Materials
Phase 2 : Development and Testing of Highly Reflective White Coatings
Phase 3 : Development and testing of Colored Highly Reflective Materials
Phase 4 : Development and testing of Colored Highly Reflective Materials with PCM
Phase 5 : Development and Testing of Thermochromic Materials
Phase 6: Development and Testing of Thermoelectric Materials

DEVELOPMENT AND TESTING OF HIGHLY REFLECTIVE WHITE MATERIALS

During the day period, maximum temperature difference between the white tiles was around 5 C as a function of their reflectivity. The difference between the white and aluminum tiles was up to 11 C.

During the night period maximum temperature difference between the white paints was around 2 C, while the maximum temperature difference between the white and the aluminum base paints was around to 5 C. In this case, the role of the emissivity is dominant.





A. Synnefa, M. Santamouris, I. Livada: A study of the thermal performance of reflective coatings for the urban environment, Solar Energy, Volume 80, Issue 8, August 2006, p.p. 968-981

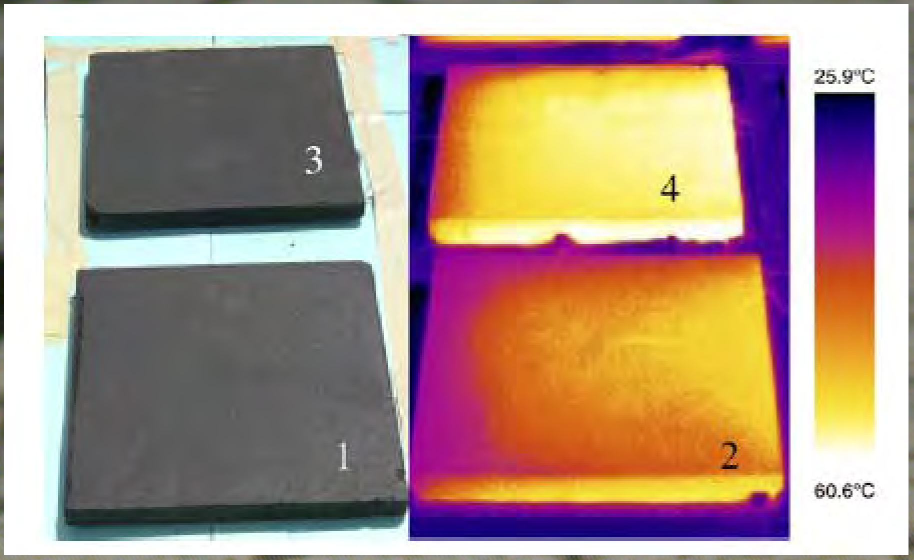
DEVELOPMENT AND TESTING OF HIGHLY REFLECTIVE COLORED MATERIALS

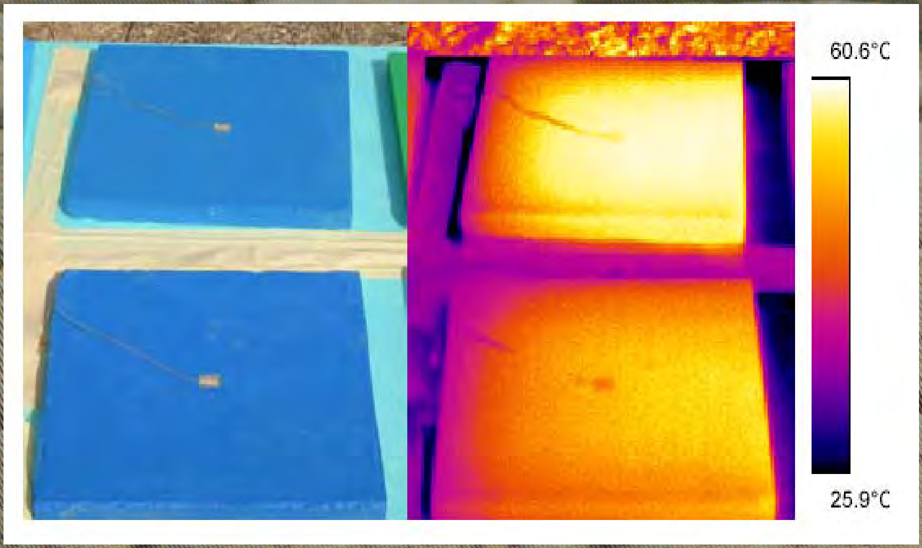
The optical properties and the thermal performance of 10 prototype cool colored coatings, prepared at the University of Athens using near-infrared reflective color pigments are tested in comparison to color- matched , conventionally pigmented coatings. The spectral reflectance was measured and the solar reflectance of the samples was calculated. The infrared emittance of the samples was also measured. The surface temperature of the coatings applied to concrete tiles was monitored on a 24 h basis from August to December 2005 in an effort to investigate the ability of the cool colored coatings to maintain lower surface temperatures than conventionally pigmented color-matched coatings under sunlight and during the night during both summer and winter.

A. Synnefa, M. Santamouris and K. Apostolakis : On the development, optical properties and thermal performance of cool colored coatings for the urban environment, Solar Energy 81 (2007) 488–497

DEVELOPMENT AND TESTING OF HIGHLY REFLECTIVE COLORED MATERIALS

During the day, all the cool colored coatings had surface temperatures lower than the colored-matched standard coatings . The best performing cool coatings were black, chocolate brown, blue and anthracite, which maintained differences in mean daily surface temperature from their respective standard color-matched coatings by 5.2, 4.7, 4.7 and 2.8 C, during the month of August. The highest temperature difference was observed between cool and standard black and was equal to 10.2 C, corresponding to a difference in their solar reflectance of 22. The lowest temperature difference was observed between cool and standard green and was equal to 1.6 C (for August) corresponding to a difference in their solar reflectance of 7.





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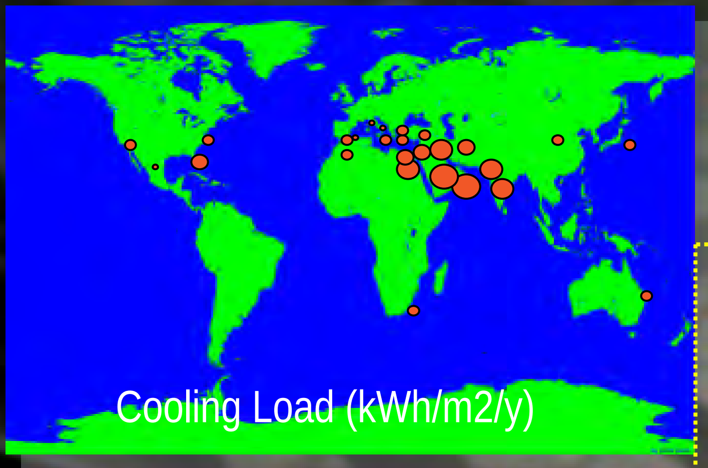
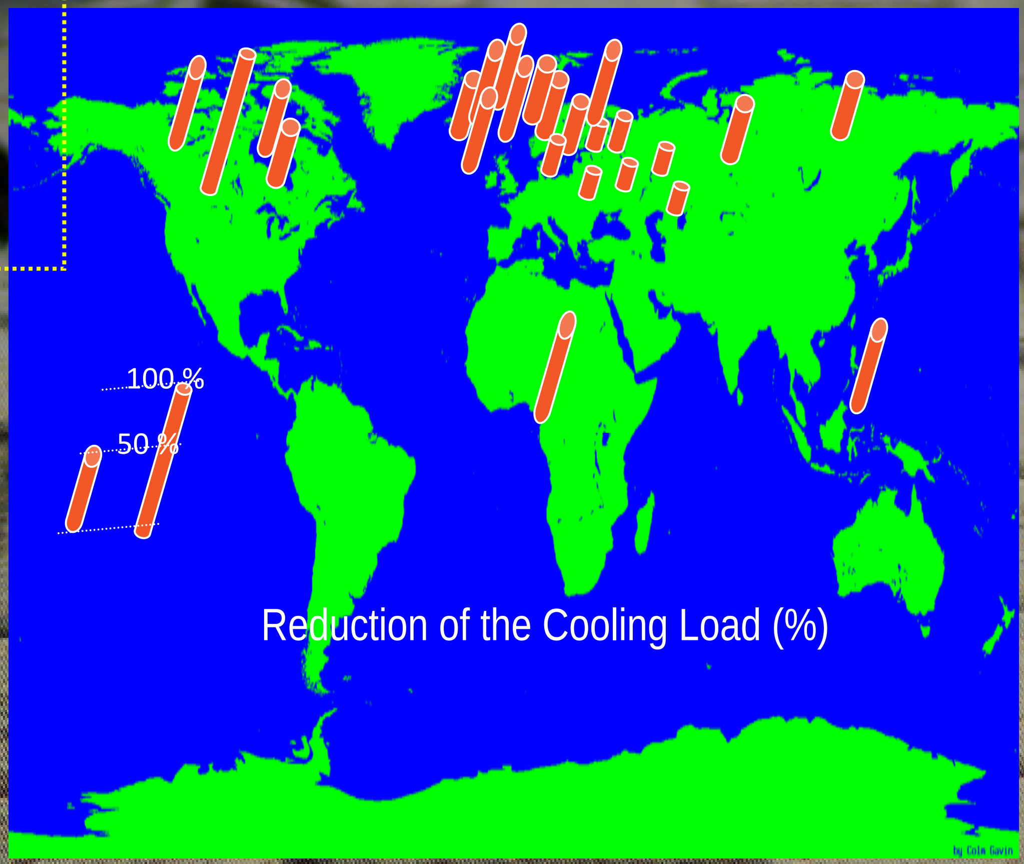
IMPACT OF REFLECTIVE COATINGS

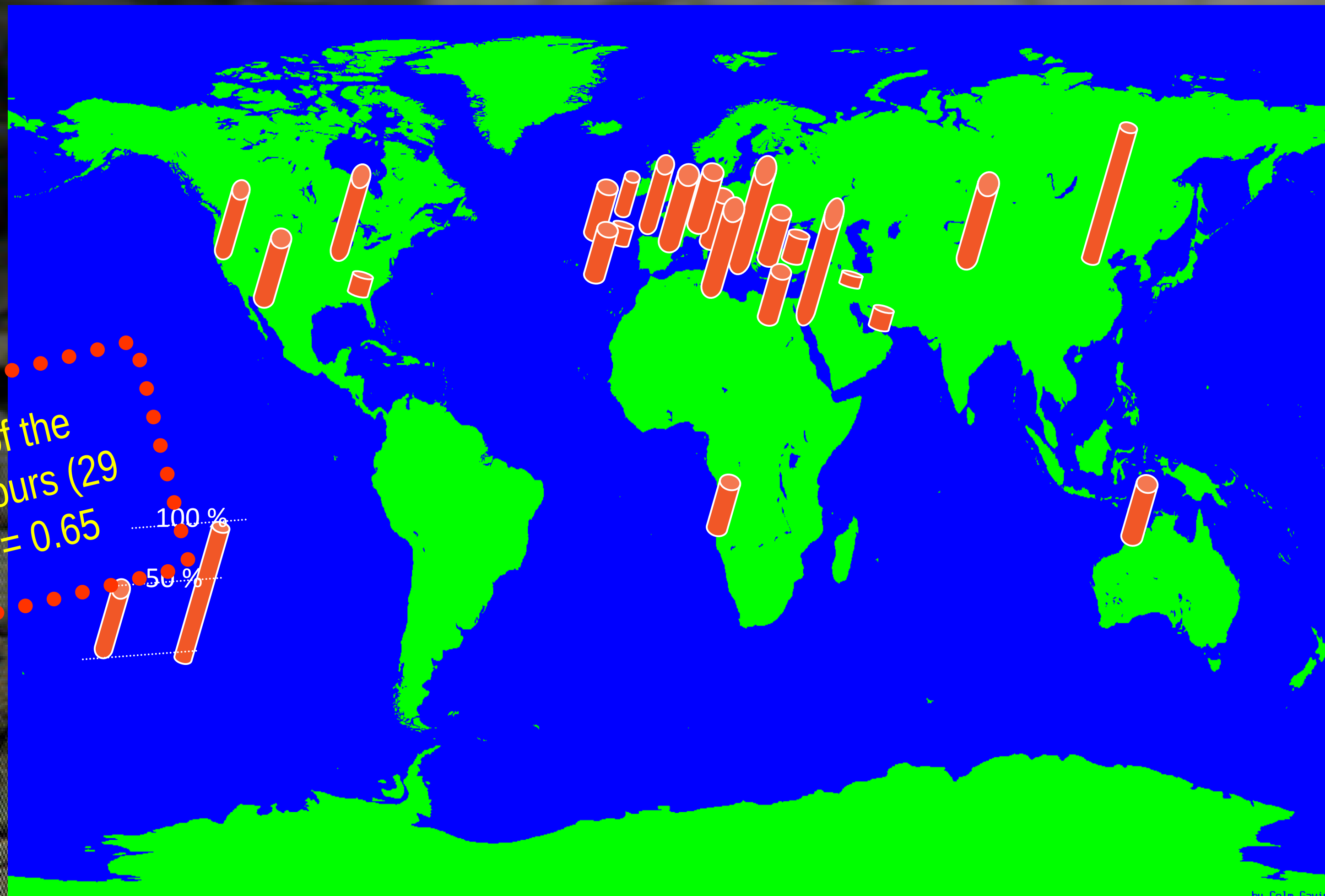


Increase of the albedo
from 0.2 to 0.85



A. Synnefa, M. Santamouris and H.Akbari: Estimating the effect of using cool coatings on energy loads and thermal comfort in residential buildings in various climatic conditions, Energy and Buildings, 39,11, 1167-1174, 2007

ENERGY IMPACT OF REFLECTIVE COATINGS



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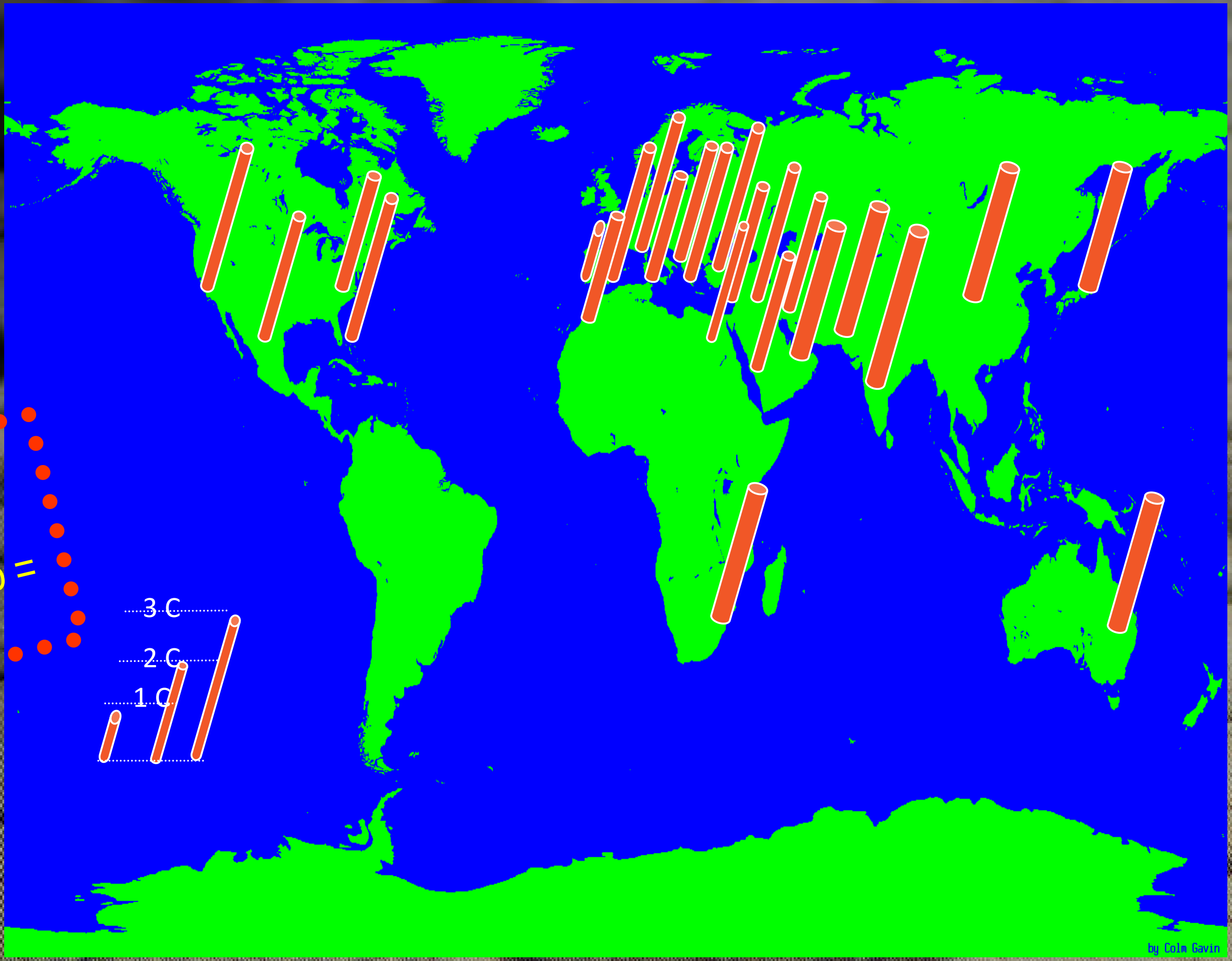
ENERGY IMPACT OF REFLECTIVE COATINGS



Decrease of the maximum indoor temperature, for Δρ = 0.65

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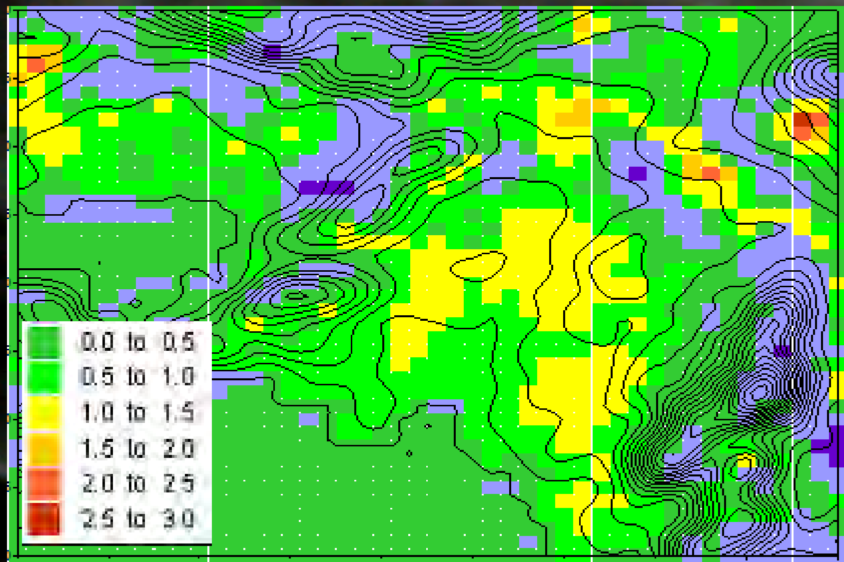
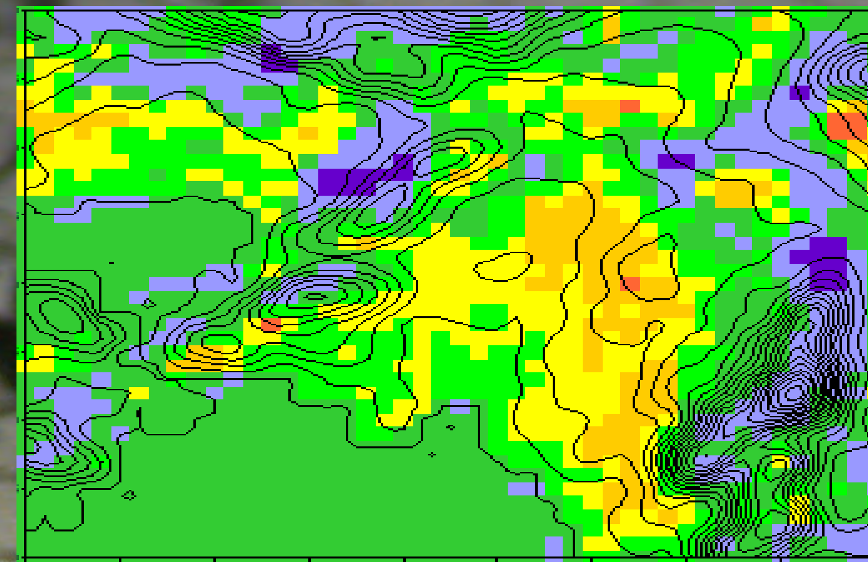
IMPACT OF REFLECTIVE COATINGS



Air temperature differences (at 2 m) between the base case and the moderate increase in albedo scenario at 14:00 LST, on the 15th of August, 2005

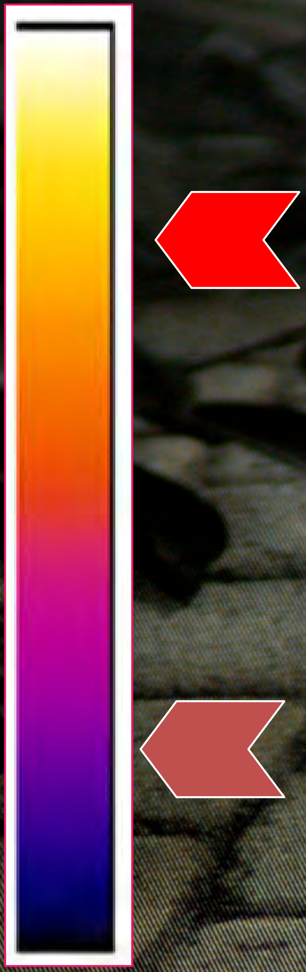


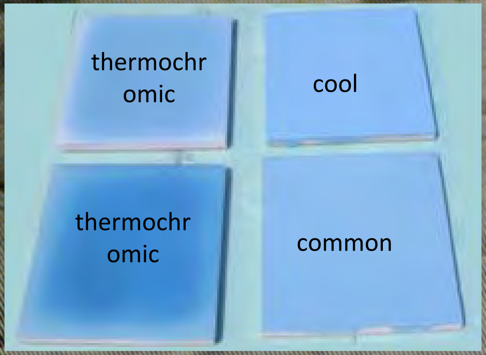
Air temperature differences between the base case and the high increase in albedo scenario at 14:00 LST, on the 15th of August, 2005

The impact of albedo changes on temperature is quite significant. The spatial distribution of temperature change correlates to the level of surface modifications in the modifiable areas. The simulations suggest that the urban areas (as well as other suburban and rural areas) are generally cooler than in the base case. The impact of albedo increase is higher at 12p.m. to 3p.m. More specifically, for the moderate increase in albedo case, the temperature depression at 12p.m. varies between 0.5 and 1.5°C. If the albedo is further increased then the temperature difference from the base case varies between 1-2 °C, with individual depressions as high as 2.2°C.

A. Synnefa, A. Dandou, M. Santamouris, M. Tombrou, N. Soulakellis : Large Scale Albedo Changes using cool materials to Mitigate Heat Island in Athens. J. Applied Met, 2008

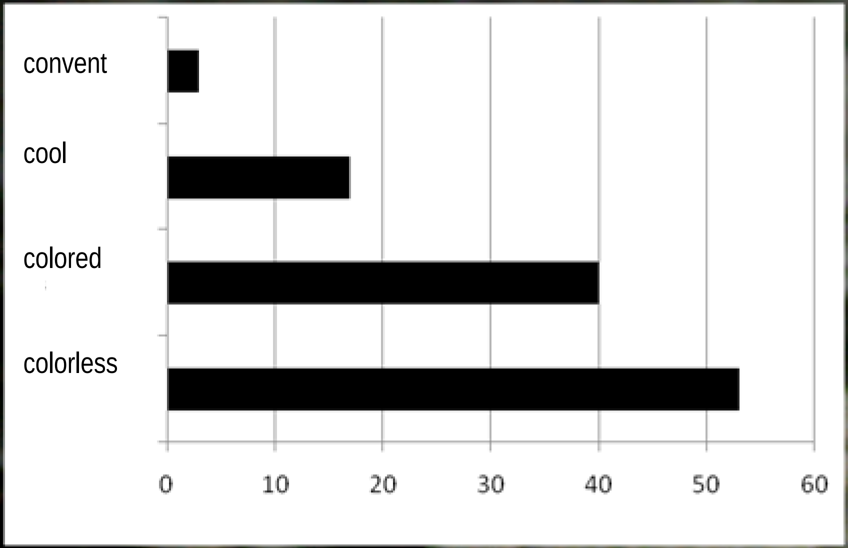
DEVELOPEMENT OF THERMOCHROMIC COATINGS

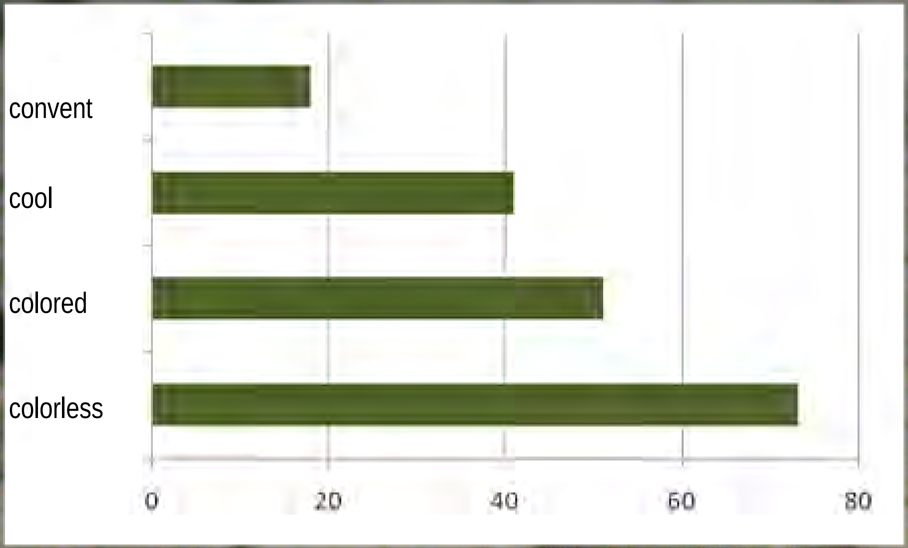


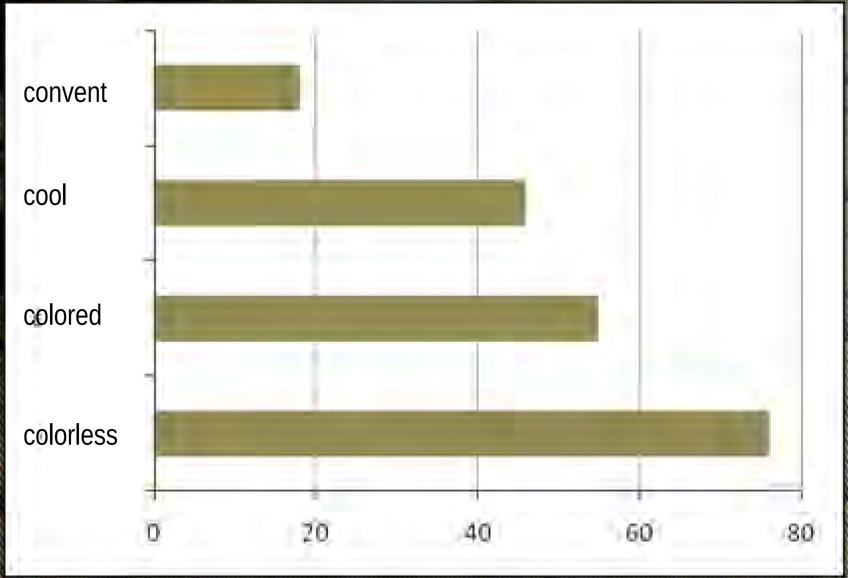


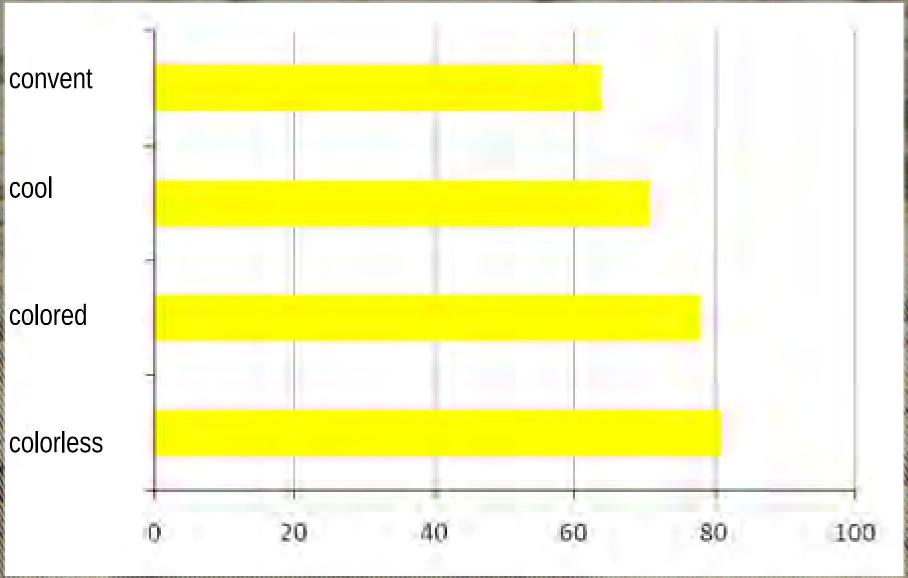
Thermochromic coatings change color as a function of the ambient temperature.
For low outdoor temperatures, winter, the coatings may be dark presenting a high absorptivity.
For higher ambient temperatures, summer, the coating becomes white presenting a high reflectivity.
Thus, when applied on roofs or walls it may present the best performance all year round.

DEVELOPEMENT OF THERMOCHROMIC COATINGS



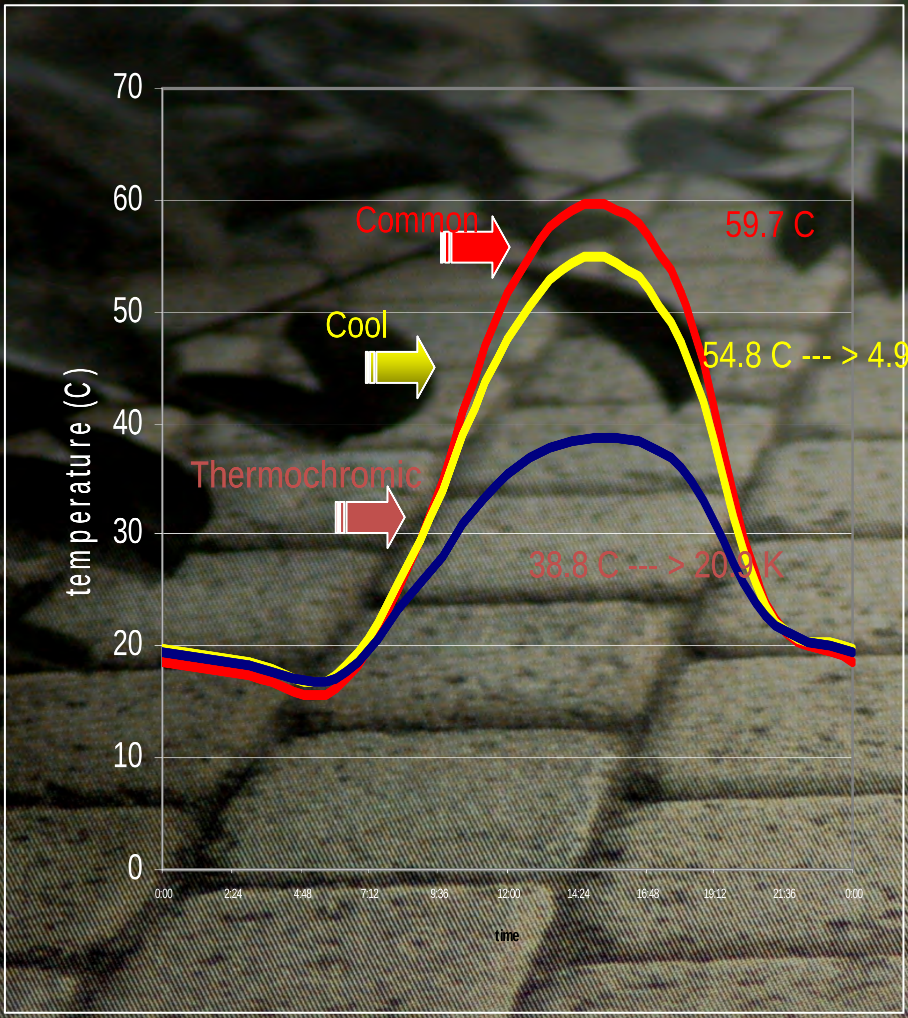


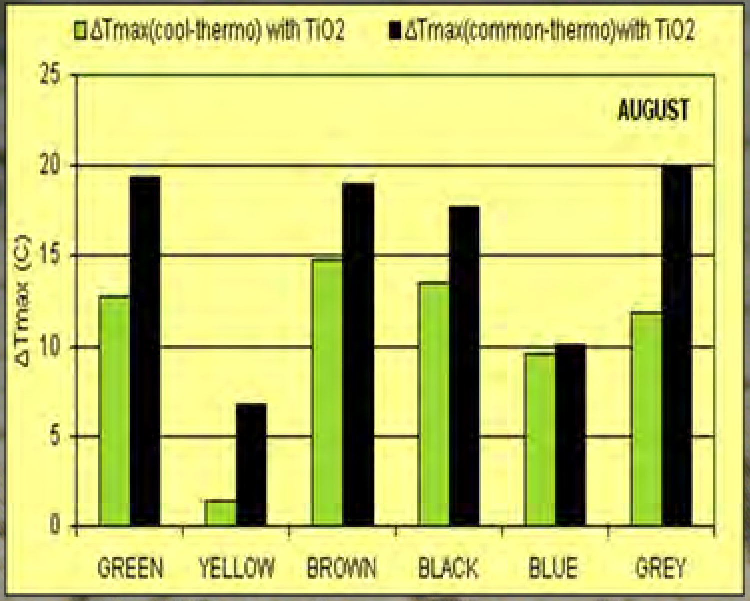


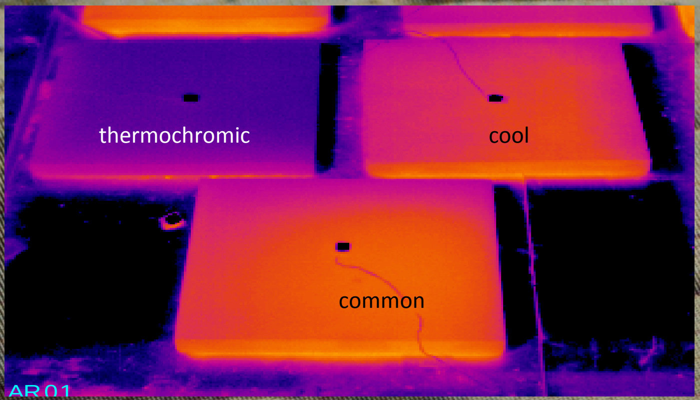


T. Karlessi, M. Santamouris, K. Apostolakis, A.Synnefa I. Livada : Development and Testing of Thermochromic coatings for Buildings and Urban Structures, Solar Energy, 2008

DEVELOPEMENT OF THERMOCHROMIC COATINGS







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Target of the COOL ROOF project:

Creation and implementation of an Action Plan for the promotion, market transformation and changing behavior towards cool roofs technology in the European Union

Cool Roofs is an EACI Project

NATIONAL AND KAPODESTRIAN UNIVERSITY OF ATHENS	NKUA	GR
Technological Educational Institute of Crete	TEIC	GR
PERDIKIS BROS CO.	ABOLIN	GR
Municipality of Kessariani	MoK	GR
Brunel University	UBRUN	UK
Greater London Authority	GLA	UK
University of la Rochelle	University of la Rochelle	FR
SIPEA HABITAT	SIPEA-Habitat	FR
Italian National Agency for New Technologies, Energy and the Environment	ENEA	IT
Regional Province of Trapani - Sector for Land Environment Natural Resources	Provincia di Trapani	IT
ECOBIOS	ECOBIOS	IT
Federation of European heating and air-conditioning associations (REHVA)	REHVA	NL
ACG Consulting Group	ACG	BE

COOL ROOFS PROJECT - OBJECTIVES

• Support policy development by transferring experience and improving understanding of the actual and potential contributions by cool roofs to heating and cooling consumption in the EU.

• Remove market barriers and simplify the procedures for cool roofs integration in construction and building's stock.

• Change the behavior of decision-makers and stakeholders so to improve acceptability of the cool roofs.

• To disseminate and promote the development of innovative legislation, codes, permits and standards, including application procedures, construction and planning permits concerning cool roofs.

COOL ROOFS PROJECT - OBJECTIVES

- Creation of a methodology for rating cool roofs products in EU market following the project's results.

- Incorporation of higher albedo surface materials in CEN technical standards for EPBD.

- Expansion of the new Agreement between EU and USA to continue the ENERGY STAR programme for office equipment to ENERGY STAR Reflective Roof Products.

- Expansion of the EU-CRC to incorporate other urban heat island mitigation techniques and experts.

- Multiplying implementation of cool roofs in EU buildings.

- Involvement of manufacturers and end users targeting to EU market transformation

COOL ROOFS PROJECT – MAIN RESULTS

Technical Axis:

1. Database of cool roofs available materials
2. Manufacturing procedures
3. At least five EU Cool Roofs case studies
4. Comparison of the cool roofs performance with other urban heat island mitigation strategies

Market Axis:

1. List of manufacturers and their available products. Analysis of the market trends for the last 10 years in comparison with US figures.
2. Strategic plan and for overcoming the already known market barriers
3. Market research with questionnaires and interviews to interested parties.
4. Pricing policies through product's benchmarking and analysis of the competitive market.

Policy Axis:

1. Analysis of the existing EU policies and legislative frameworks that can integrate cool roofs' incentives and measures.
2. Analysis of existing policies and legislative framework in the participating countries.
3. Analysis of the local incentives, rebates and funding schemes that can be utilised for the promotion of cool roofs.
4. Formulation of concrete and clear proposals to the local stakeholders via the EU-CRC network for the benefits of providing incentives for cool roofs as well as promotion of "cool roofs local programmes" via the creation of the shinning examples with documented analysis of the benefits, following the US examples.

COOL ROOFS PROJECT – MAIN RESULTS

<u>End Users Axis (disseminaiton and promotion):</u>

1. Workshops and seminars in local level.
2. Creation of brochures and dissemination material.
3. Creation of marketing spots.
4. Organising visits to the shinning examples
5. Participation to an International Conference and
6. Web Portal.