RECENT PROGRESS ON LOCAL CLIMATE CHANGE MITIGATION TECHNOLOGIES

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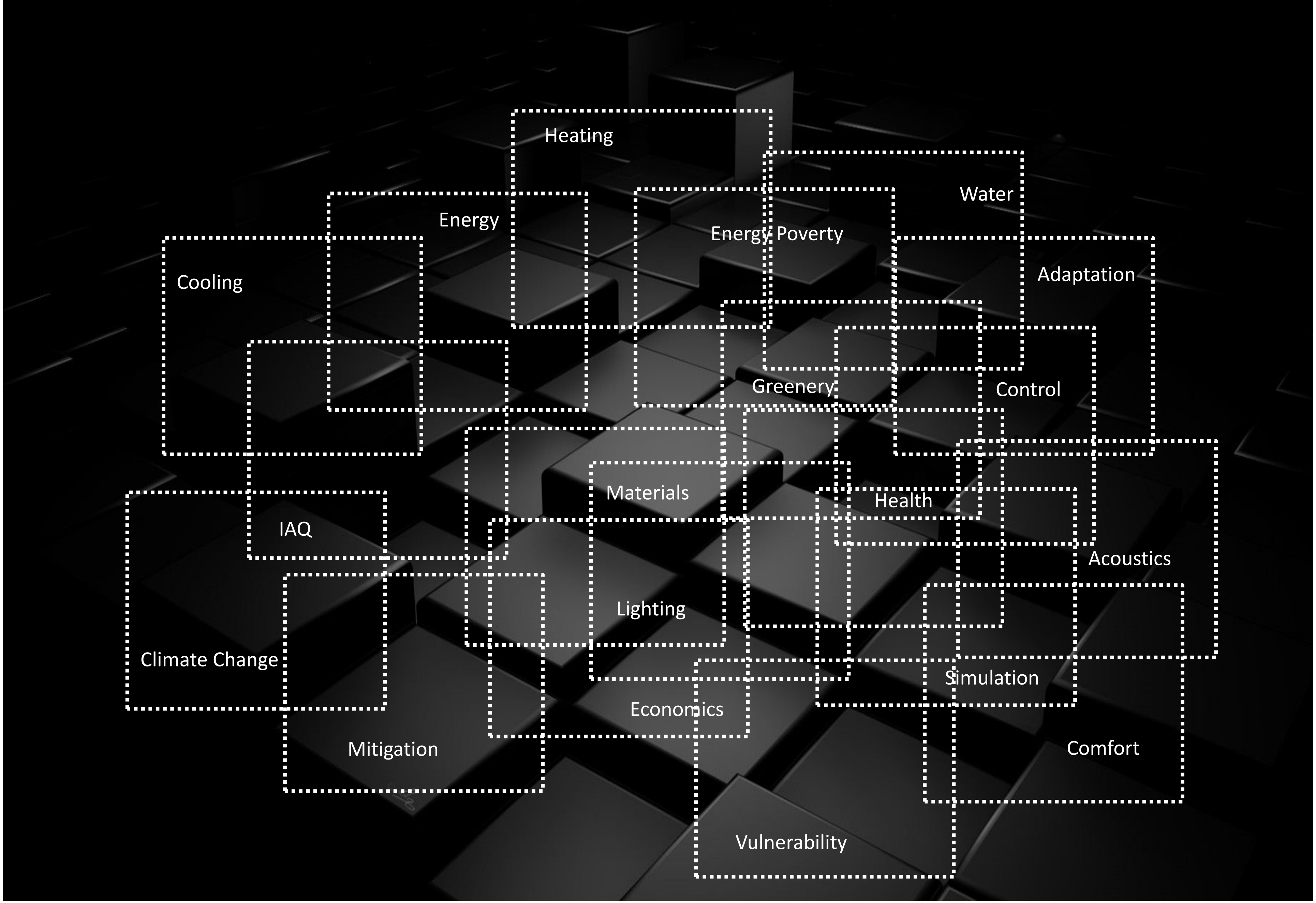
BUILT ENVIRONMENT – A DEEP NEED FOR KNOWLEDGE AND INNOVATION



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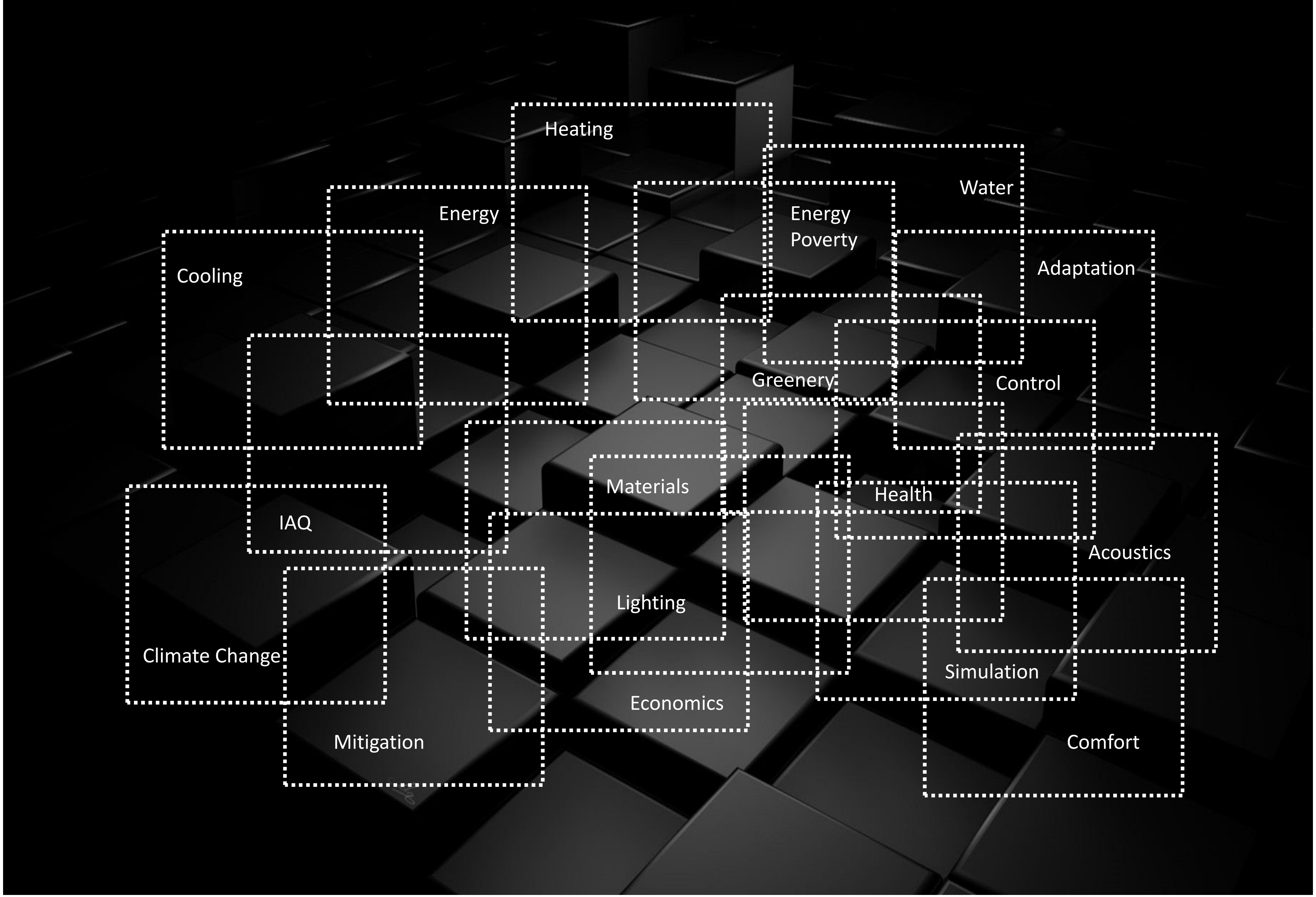
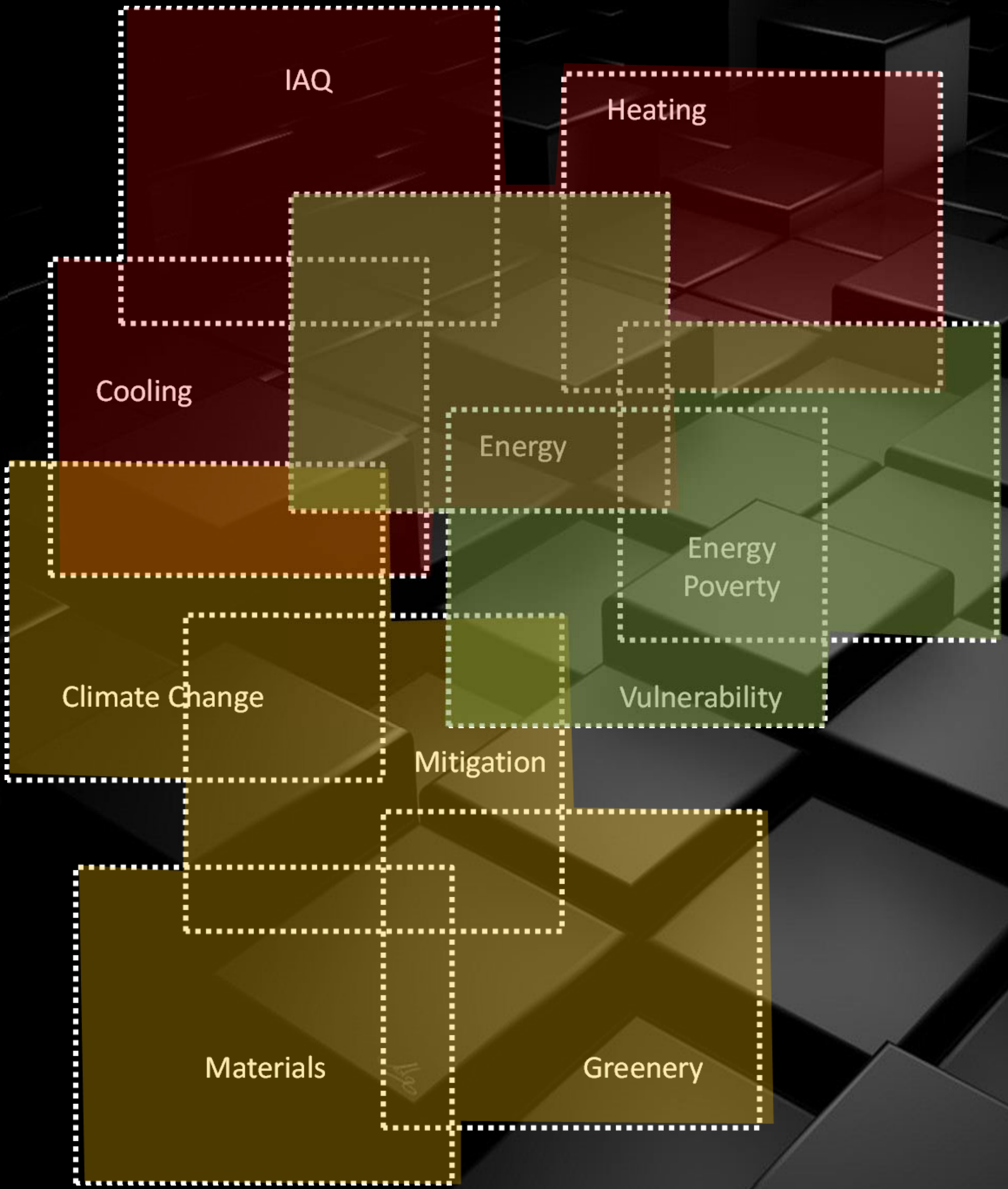


BUILT ENVIRONMENT – A DEEP NEED FOR KNOWLEDGE AND INNOVATION

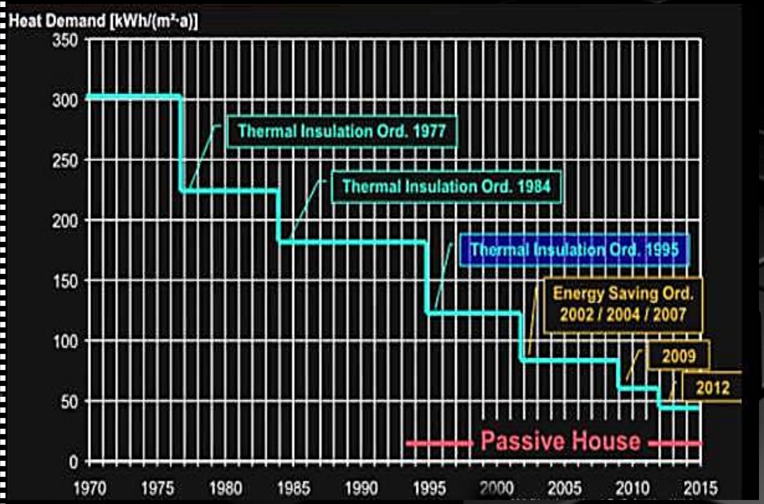


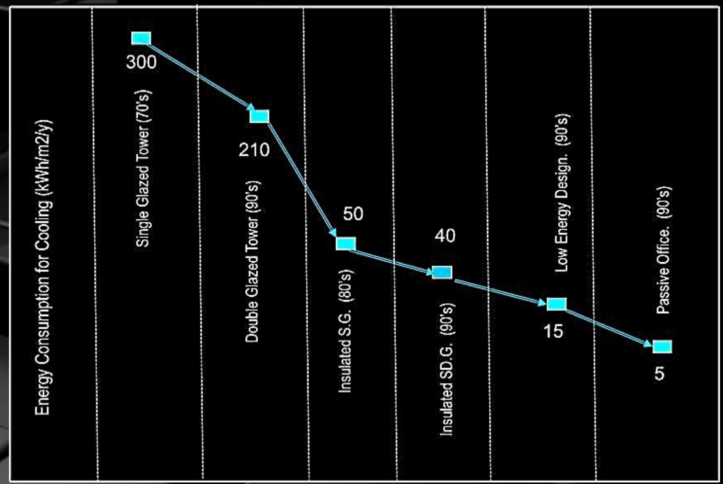
The three sectors are strongly interrelated, presenting very significant synergies.

Existing research aiming to reduce the energy consumption in buildings usually underestimates the importance and the impact of the local and global climate change as well as the technical, social and economic implications related to the energy poverty.

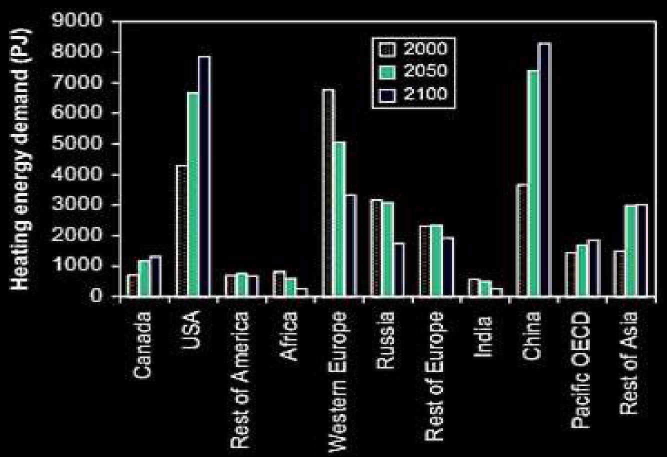
Failure to consider all issues in an integrated and holistic way may inevitably result in higher energy consumption and social discrepancies.

RESEARCH ON THE ENERGY CONSUMPTION OF BUILDINGS





Source : Isaac and Van Vuuren



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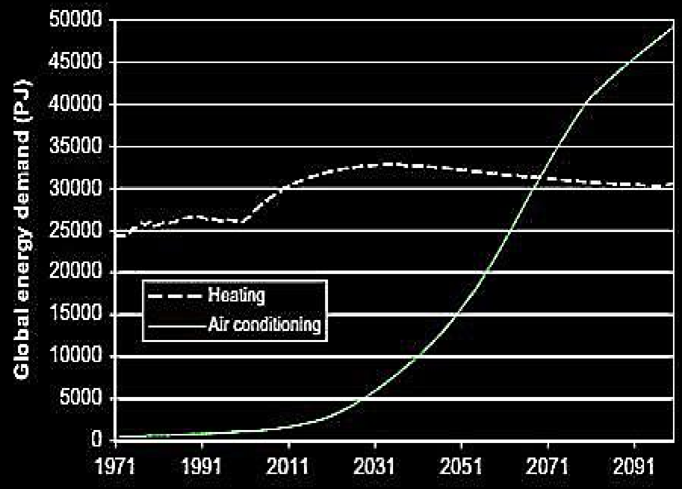
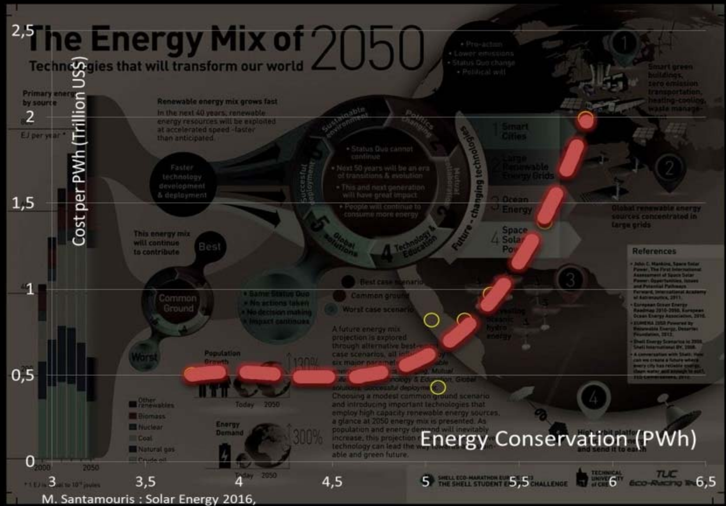
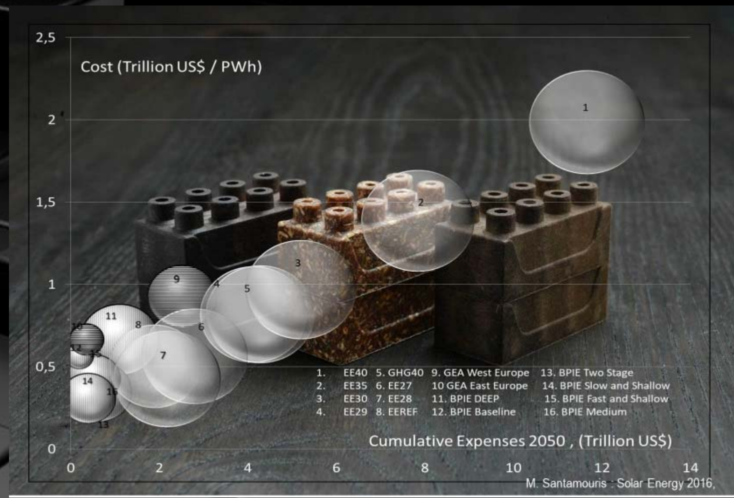


RESEARCH ON THE ENERGY CONSUMPTION OF BUILDINGS

Source : Santamouris



Source : Santamouris



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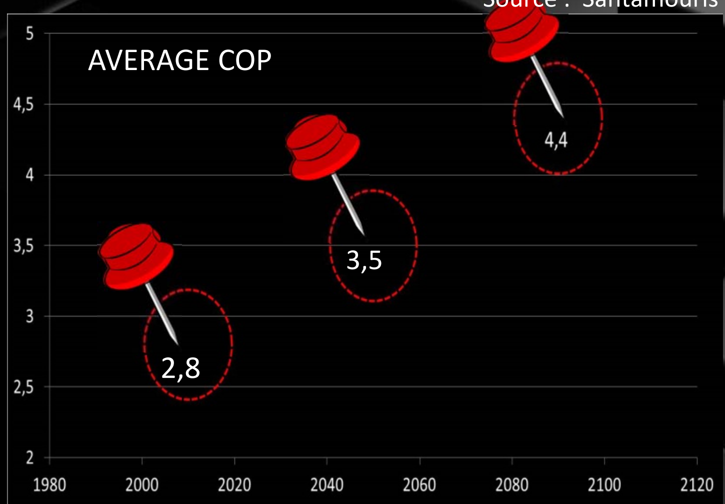

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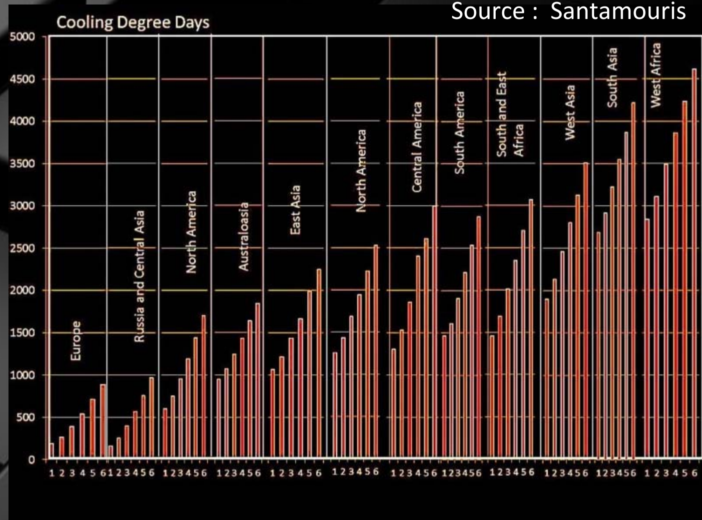
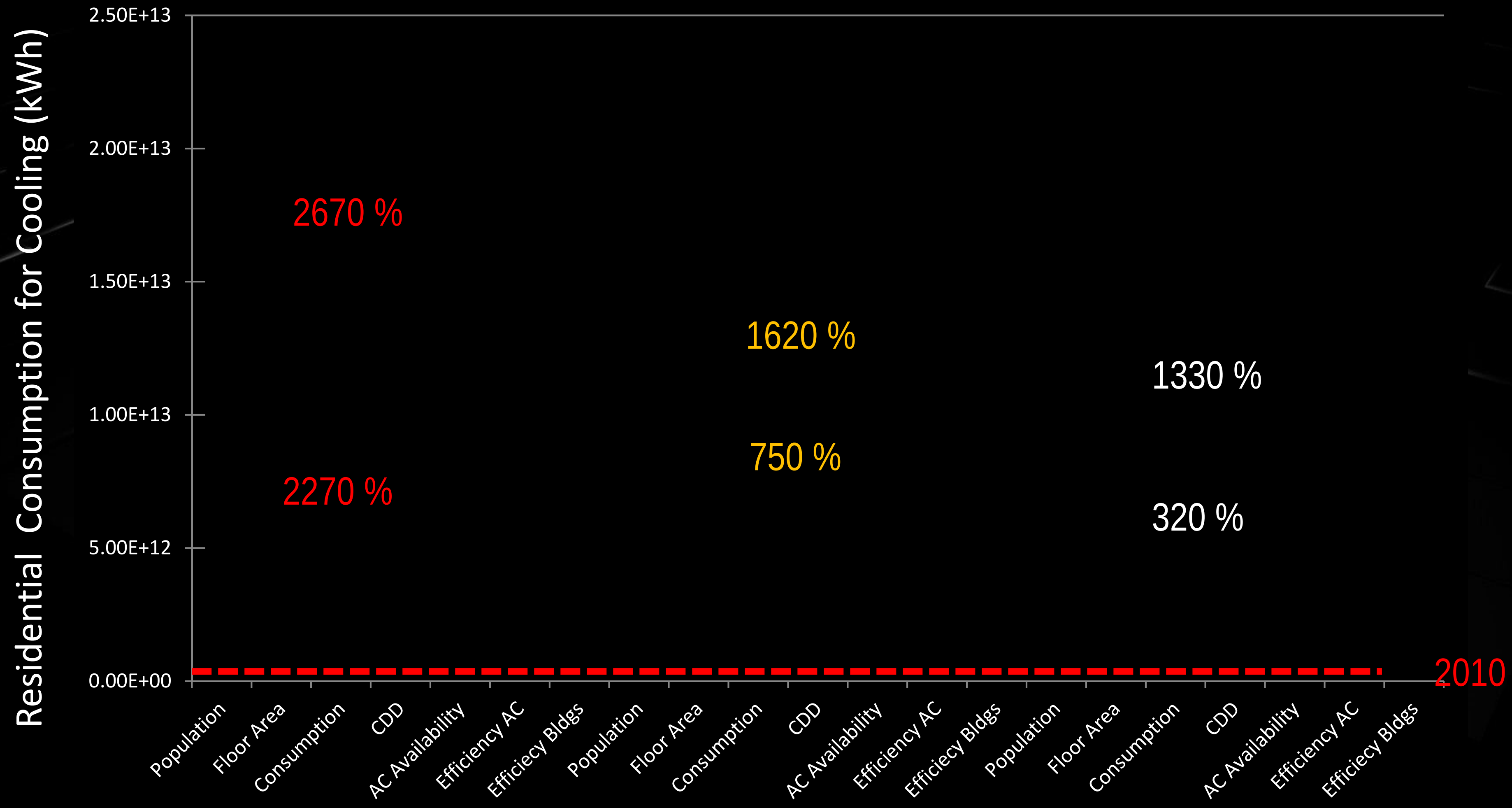


RESEARCH ON THE ENERGY CONSUMPTION OF BUILDINGS

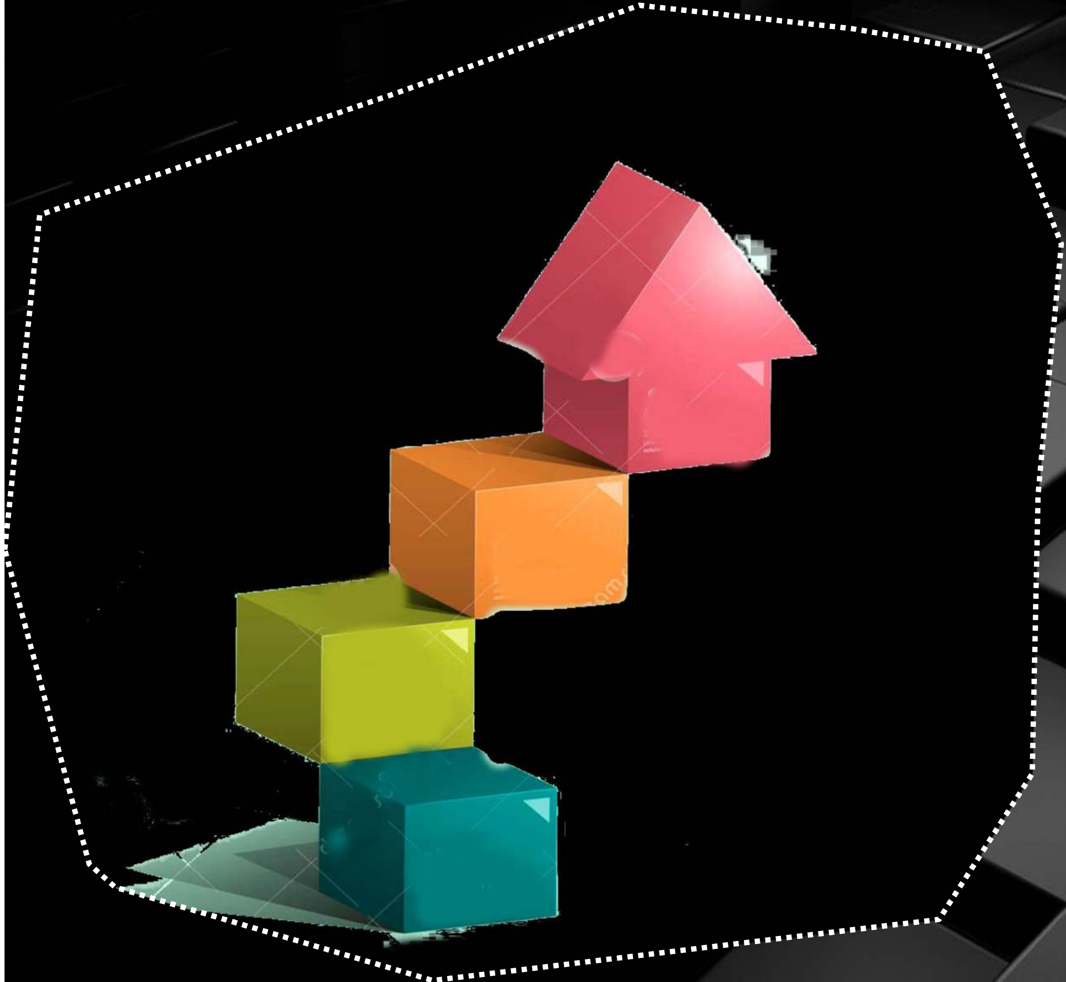
The 2050 Cooling Consumption of Residential Buildings

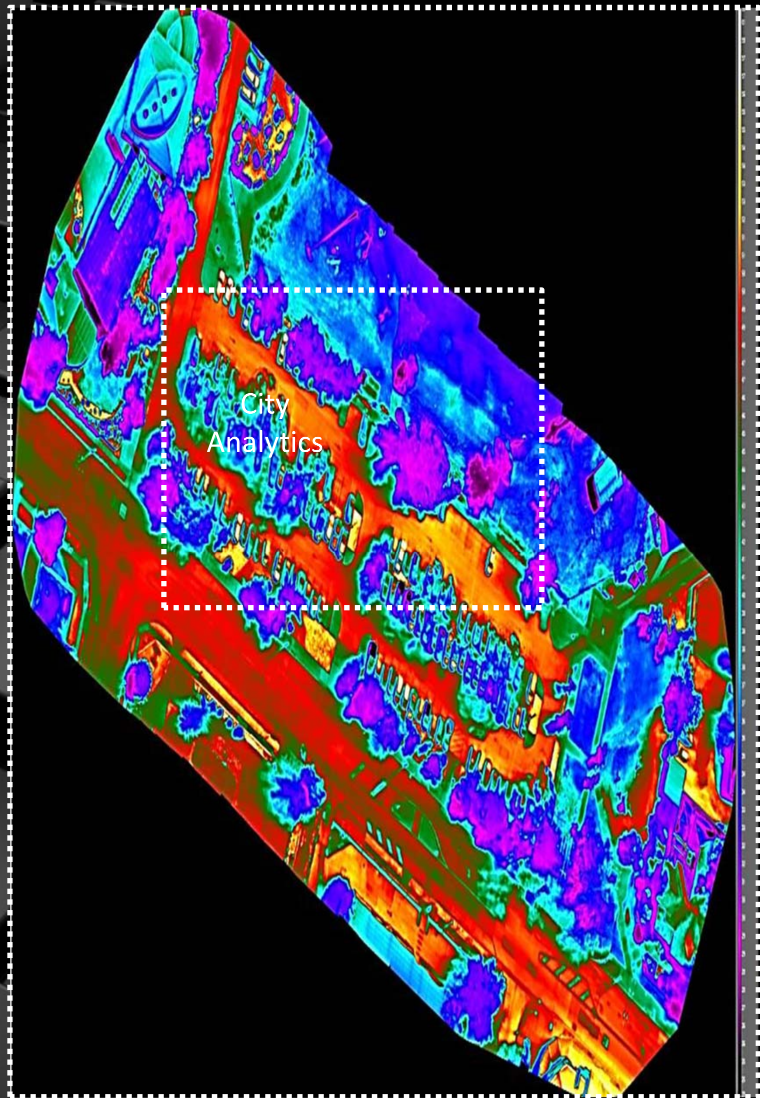


Source : M. Santamouris : Cooling of Buildings. Past, Present and Future, Energy and Buildings, 128 (2016) 617–638, 2016

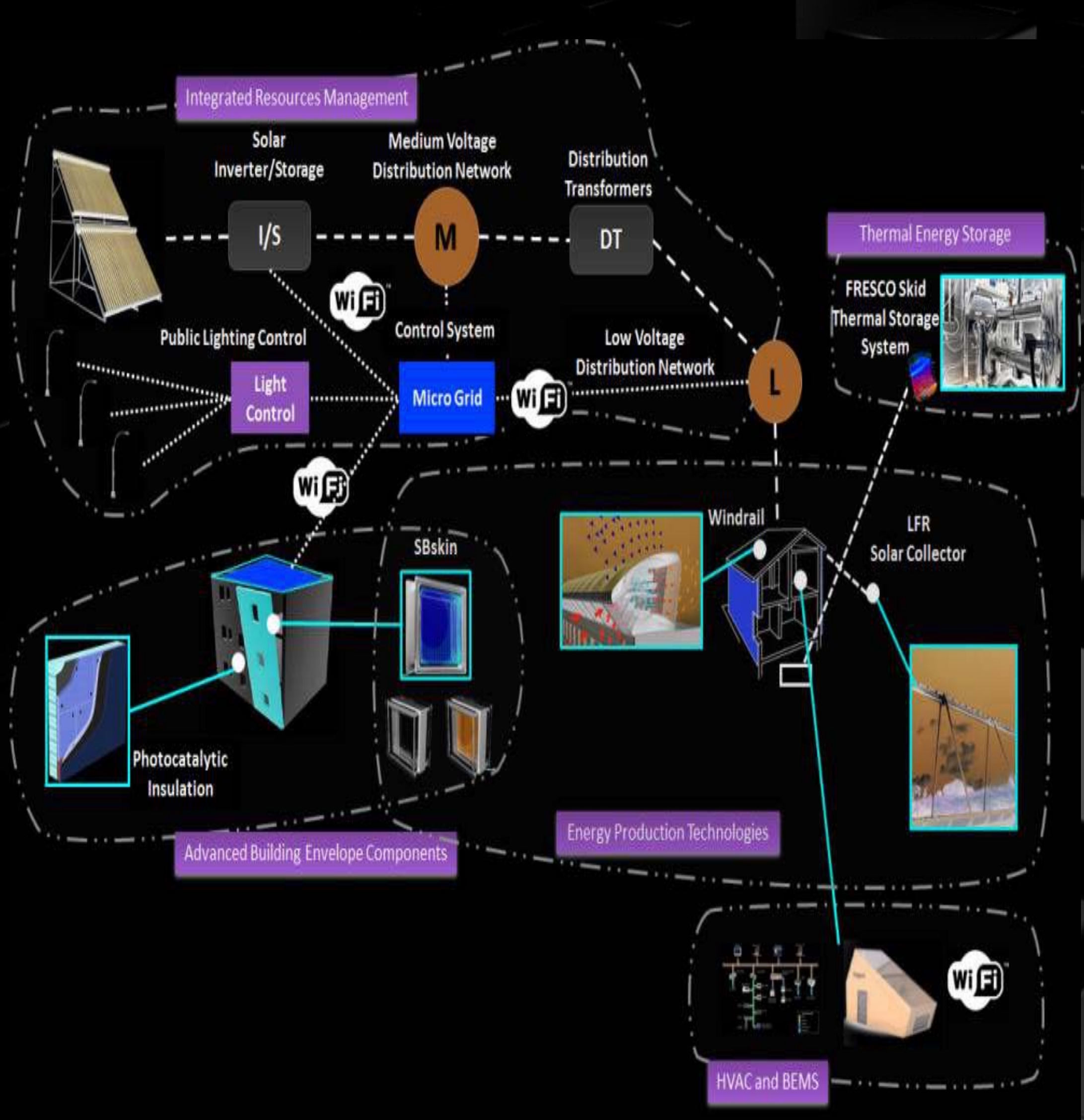
RESEARCH ON THE ENERGY CONSUMPTION OF BUILDINGS

From the Individual Building to Settlements and Cities

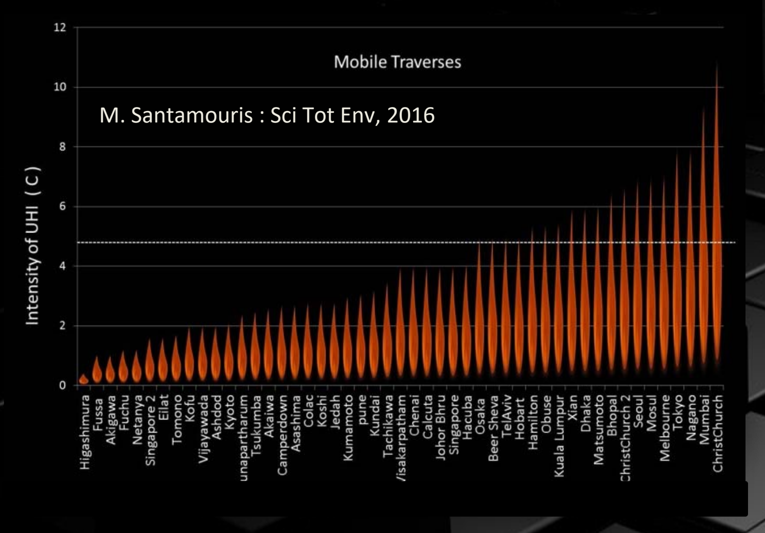


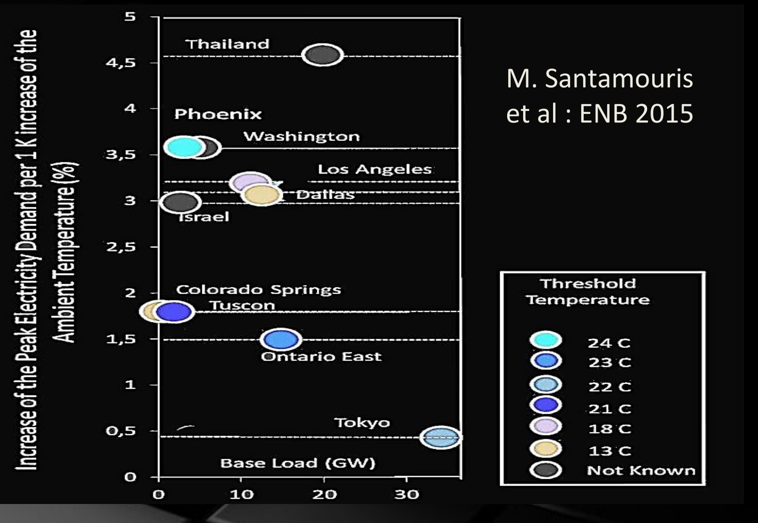


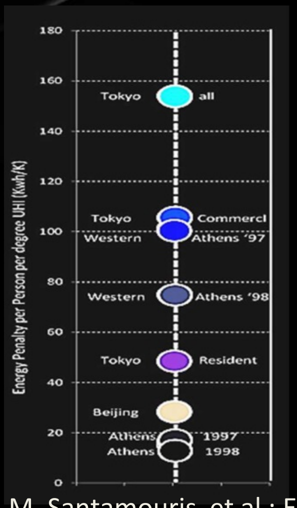
Zero Energy Settlements –Zero Plus Settlements



Local Climate Change – Evidence and Impact







M. Santamouris et al : ENB 2014

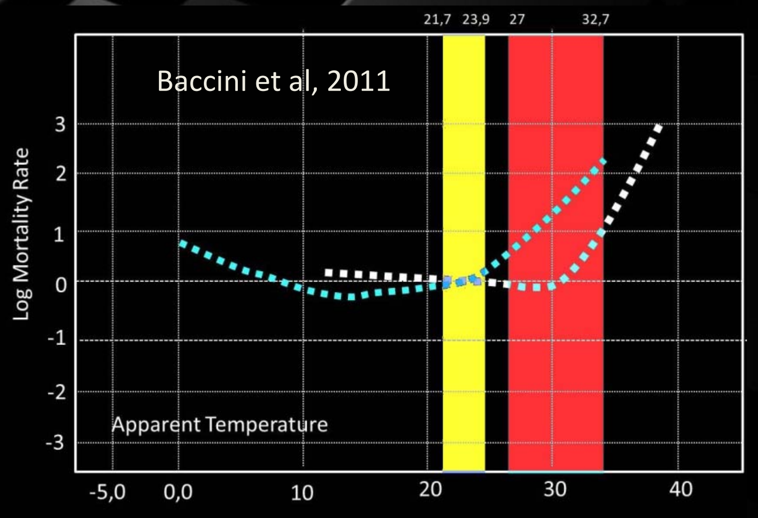
Global Energy Penalty per Person and per degree of the UHI intensity, GEPPI

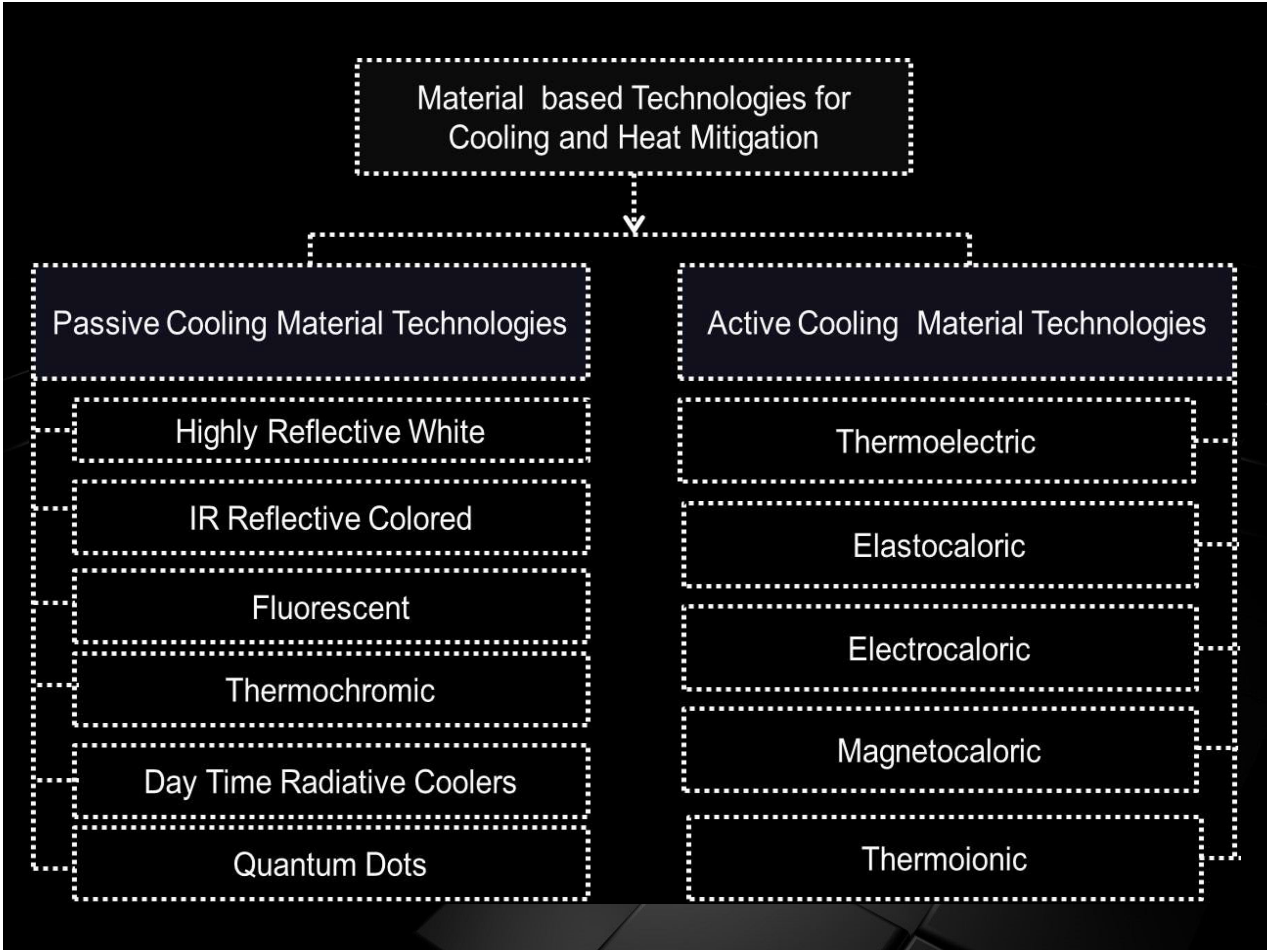
It has the same characteristics as the GEPP index while it includes the local UHI intensity as additional information.

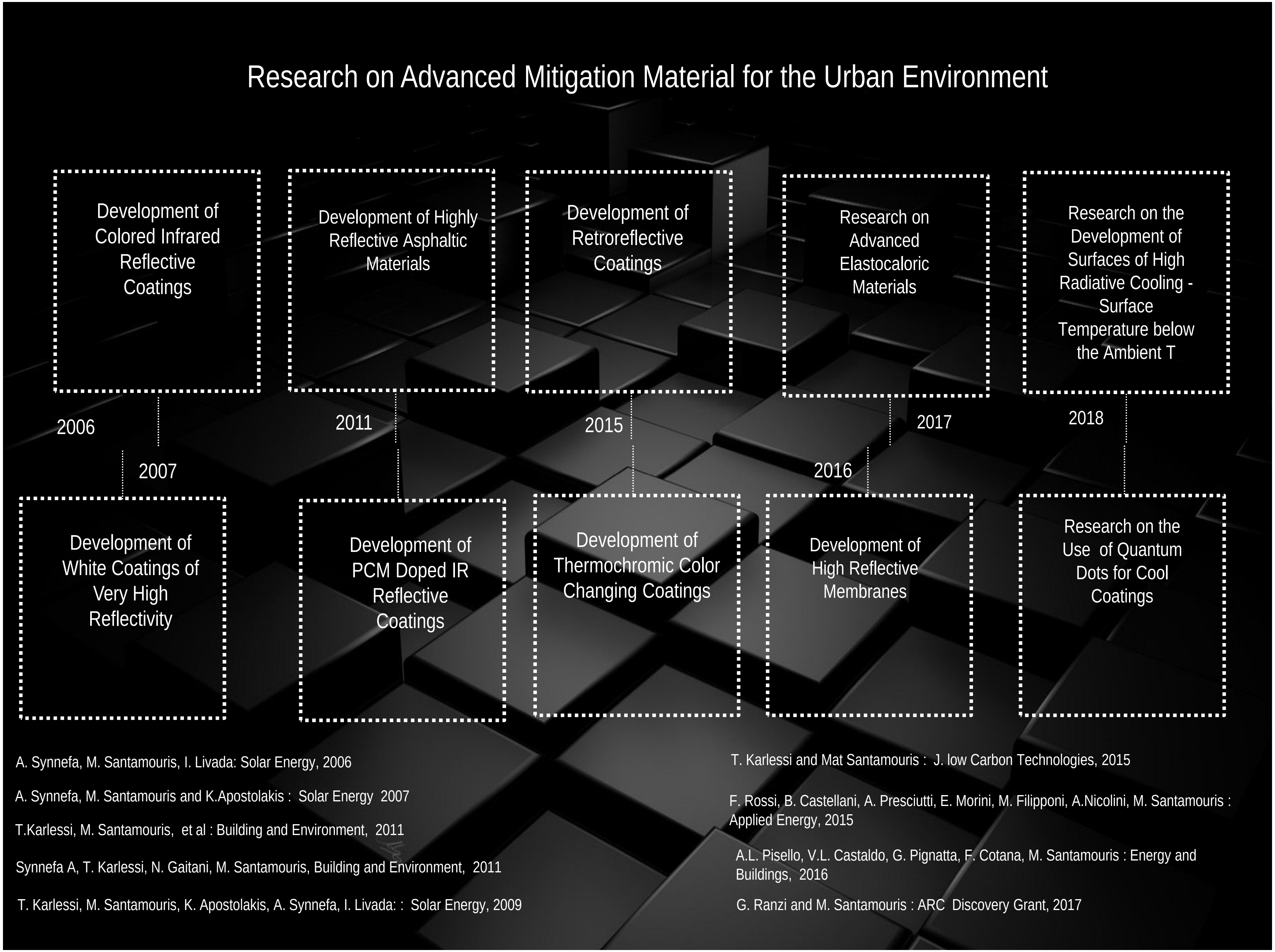
Values of GEPPI varied between 15 kWh/k for the Municipality of Athens to 154 kWh/K for Tokyo.

UHI triggers an average Global Energy Penalty per Person and per degree of the UHI intensity, GEPPI, close to

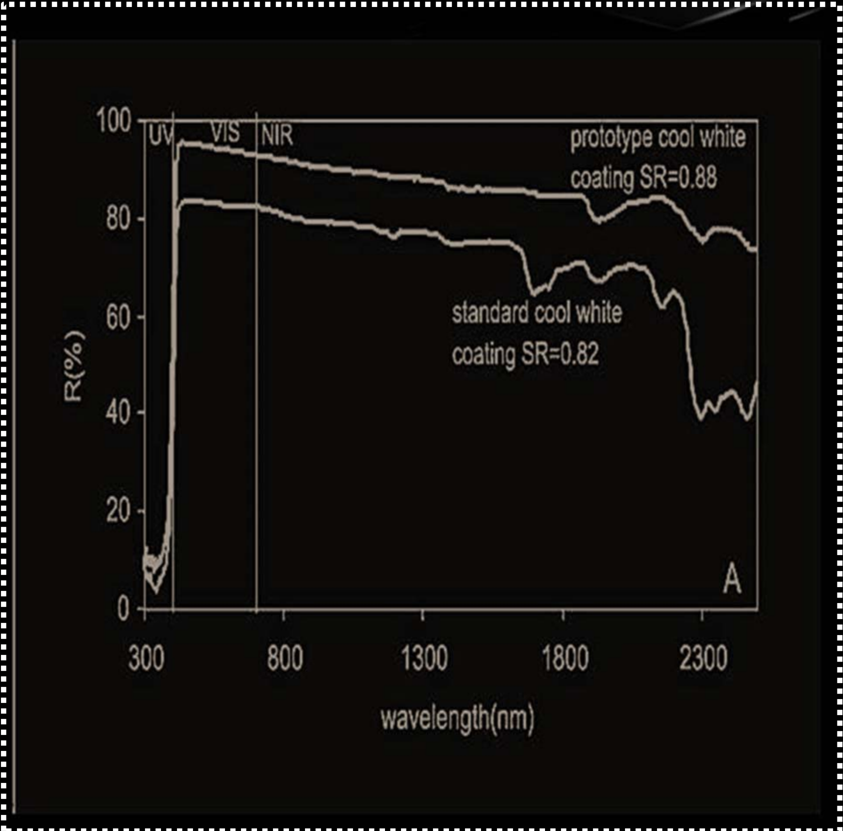
68 kWh/p/K.

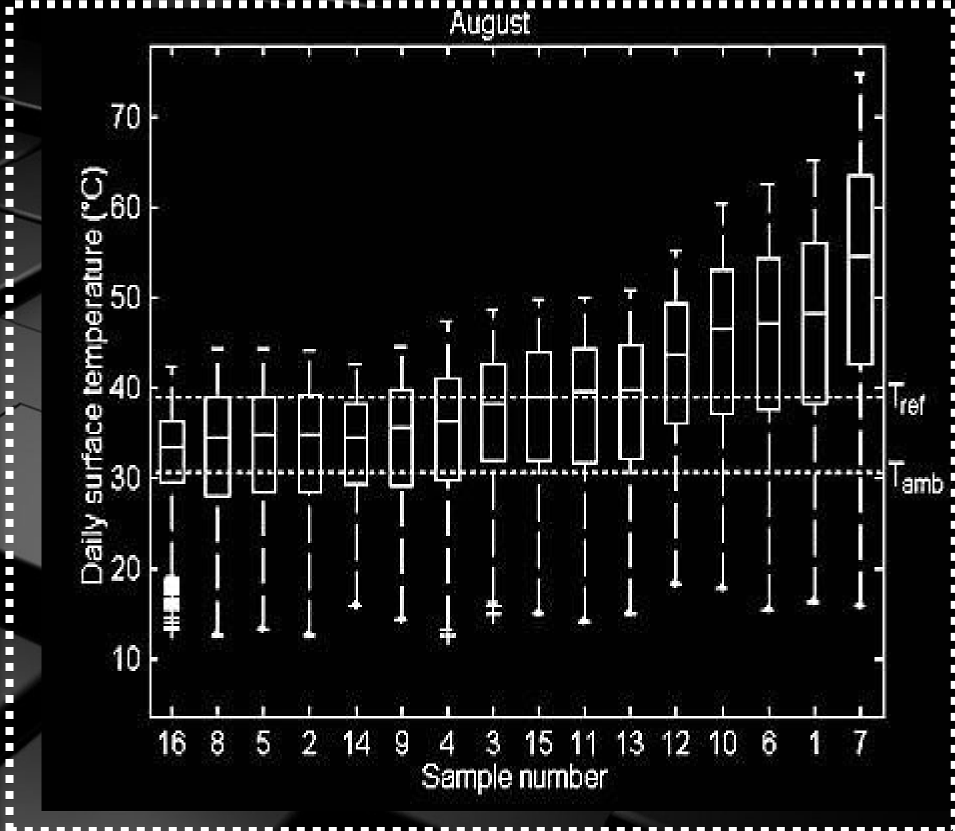



Material based Technologies for Cooling and Heat Mitigation
Passive Cooling Material Technologies
Highly Reflective White
IR Reflective Colored
Fluorescent
Thermochromic
Day Time Radiative Coolers
Quantum Dots
Active Cooling Material Technologies
Thermoelectric
Elastocaloric
Electrocaloric
Magnetocaloric
Thermoionic


Research on Advanced Mitigation Material for the Urban Environment
Development of Colored Infrared Reflective Coatings
2006
2007
Development of White Coatings of Very High Reflectivity
Development of Highly Reflective Asphaltic Materials
2011
Development of PCM Doped IR Reflective Coatings
Development of Retroreflective Coatings
2015
Development of Thermochromic Color Changing Coatings
Research on Advanced Elastocaloric Materials
2017
2016
Development of High Reflective Membranes
Research on the Development of Surfaces of High Radiative Cooling - Surface Temperature below the Ambient T
2018
Research on the Use of Quantum Dots for Cool Coatings
A. Synnefa, M. Santamouris, I. Livada: Solar Energy, 2006
A. Synnefa, M. Santamouris and K.Apostolakis : Solar Energy 2007
T.Karlessi, M. Santamouris, et al : Building and Environment, 2011
Synnefa A, T. Karlessi, N. Gaitani, M. Santamouris, Building and Environment, 2011
T. Karlessi, M. Santamouris, K. Apostolakis, A. Synnefa, I. Livada: : Solar Energy, 2009
T. Karlessi and Mat Santamouris : J. low Carbon Technologies, 2015
F. Rossi, B. Castellani, A. Presciutti, E. Morini, M. Filipponi, A.Nicolini, M. Santamouris : Applied Energy, 2015
A.L. Pisello, V.L. Castaldo, G. Pignatta, F. Cotana, M. Santamouris : Energy and Buildings, 2016
G. Ranzi and M. Santamouris : ARC Discovery Grant, 2017

Research on Advanced Mitigation Material for the Urban Environment
White Coatings of Very High Reflectivity

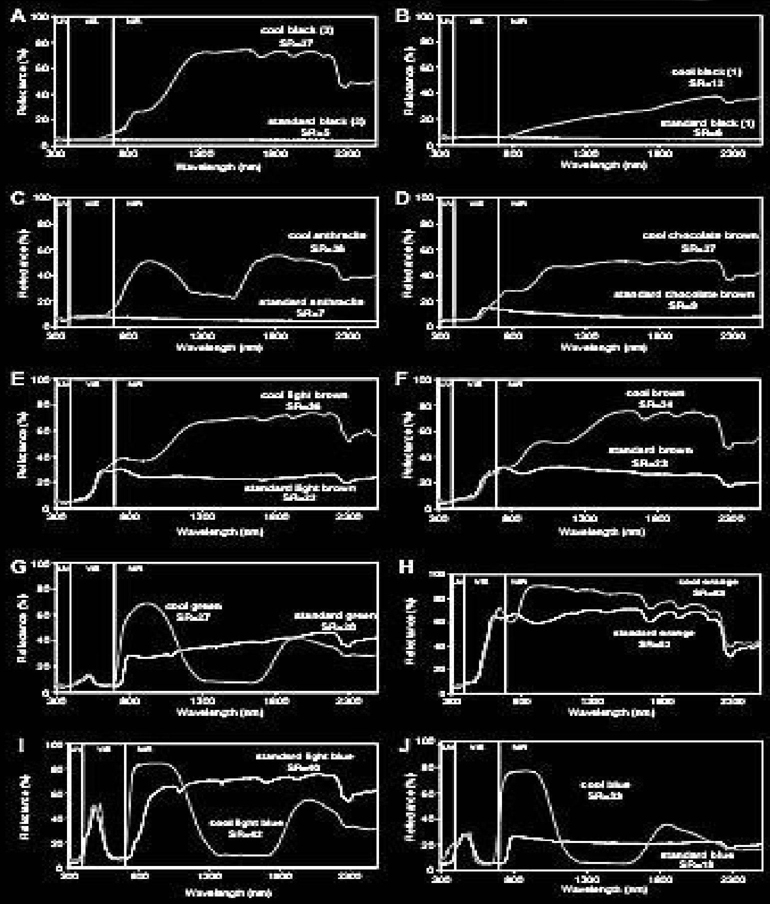




Source : A. Synnefa and
M. Santamouris

A study of the thermal performance of reflective coatings for the urban environment, Solar Energy, Volum
80, Issue 8, August 2006, p.p. 968-981.

Research on Advanced Mitigation Material for the Urban Environment
Colored IR reflecting Coatings



Source : A. Synnefa
M. Santamouris et al

On the development, optical properties and thermal performance of cool colored coatings for the urban environment, Solar Energy 81 (2007) 488–497

Research on Advanced Mitigation Material for the Urban Environment
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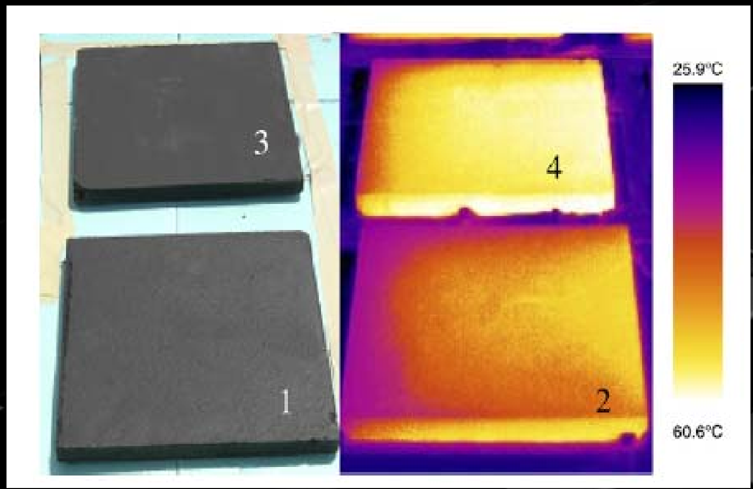

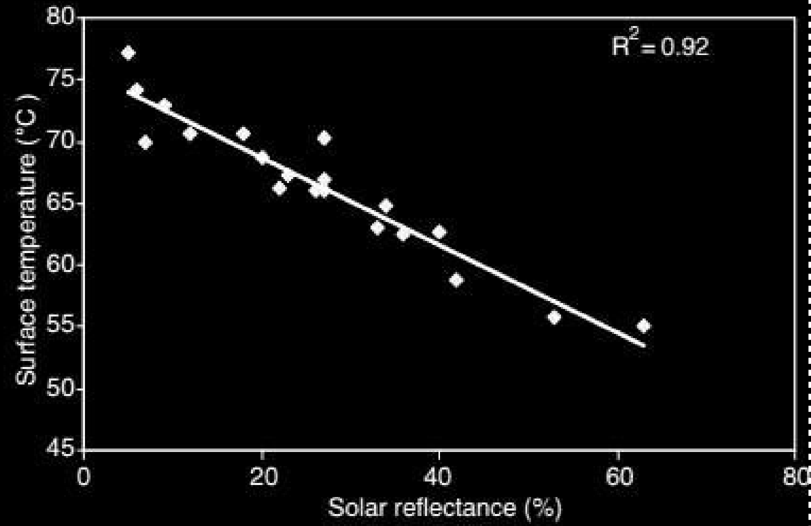

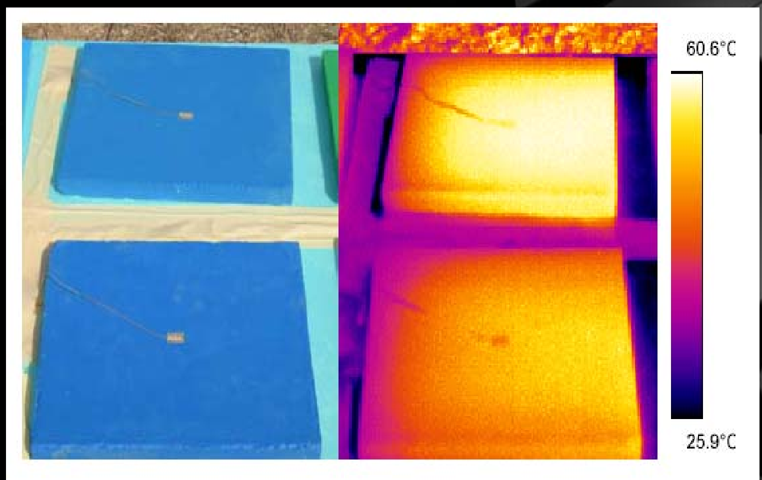

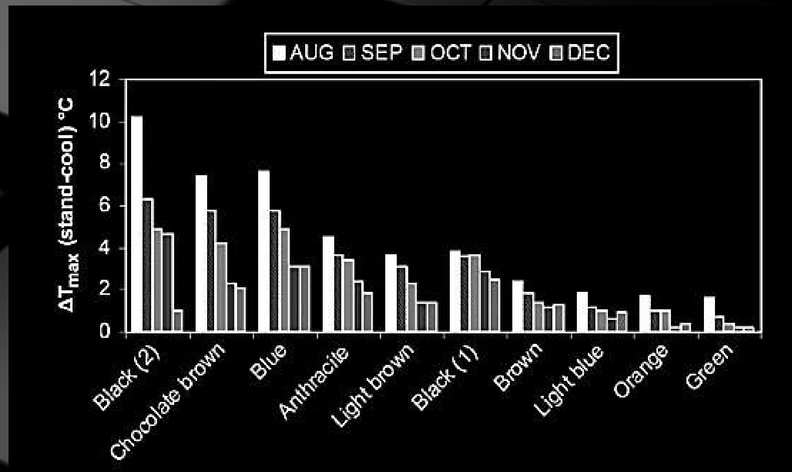

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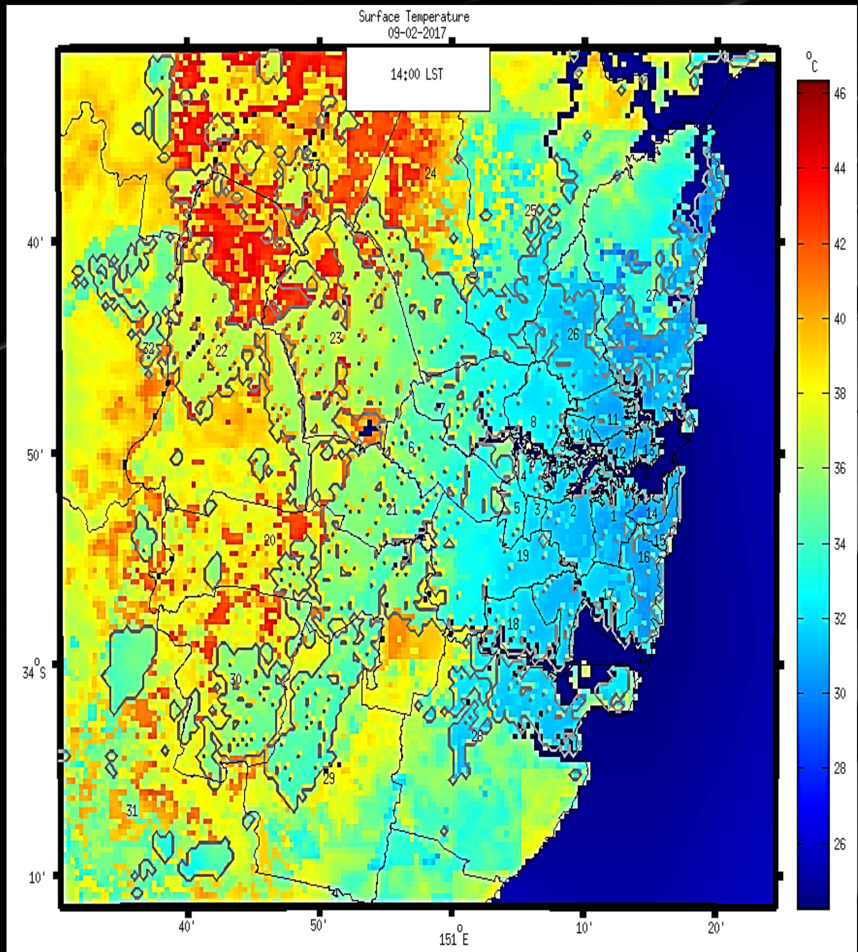
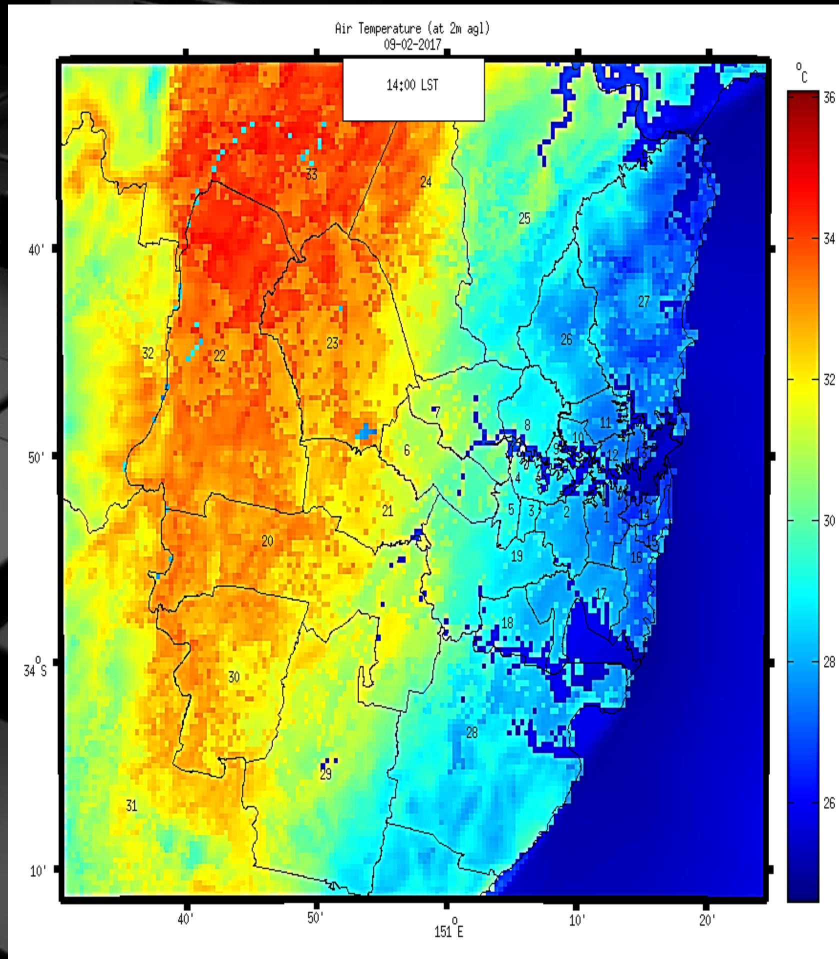
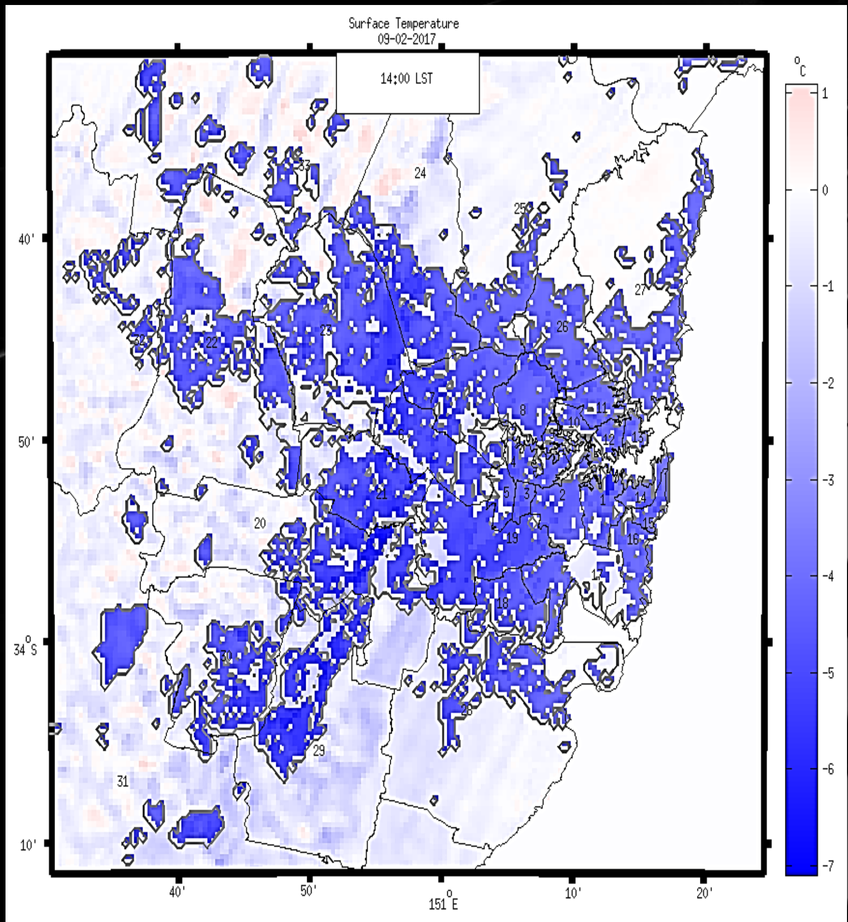
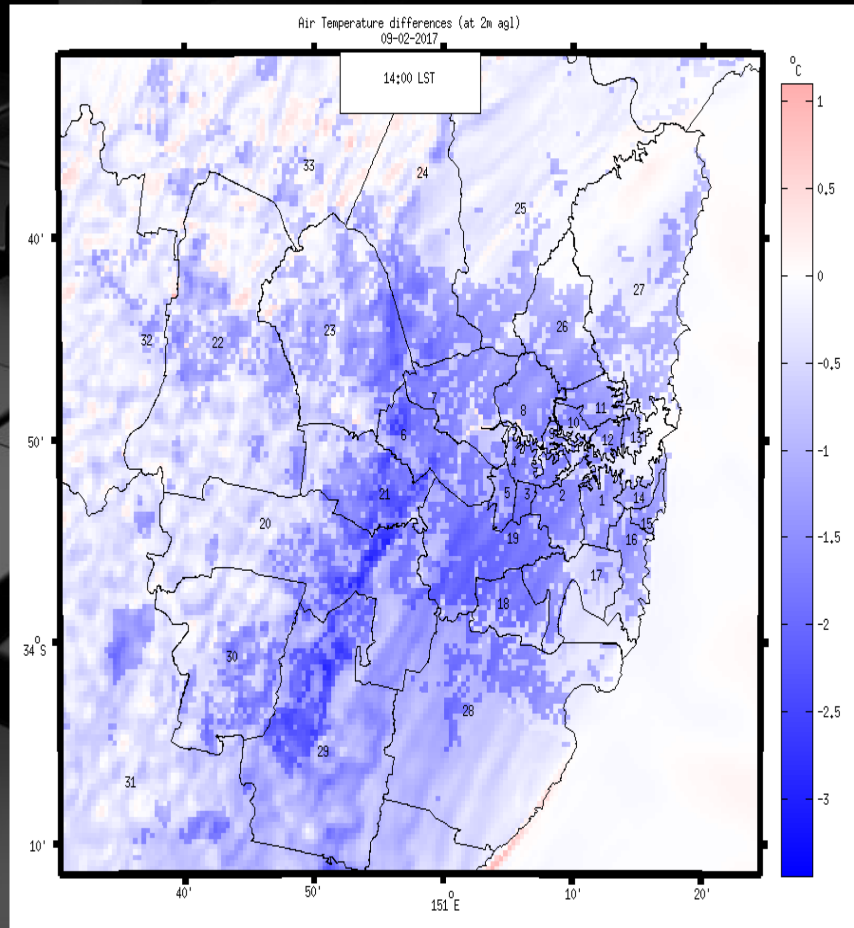




M. Santamouris et al : Cooling Parramatta, Not published article

Research on Advanced Mitigation Material for the Urban Environment
Colored IR reflecting Coatings





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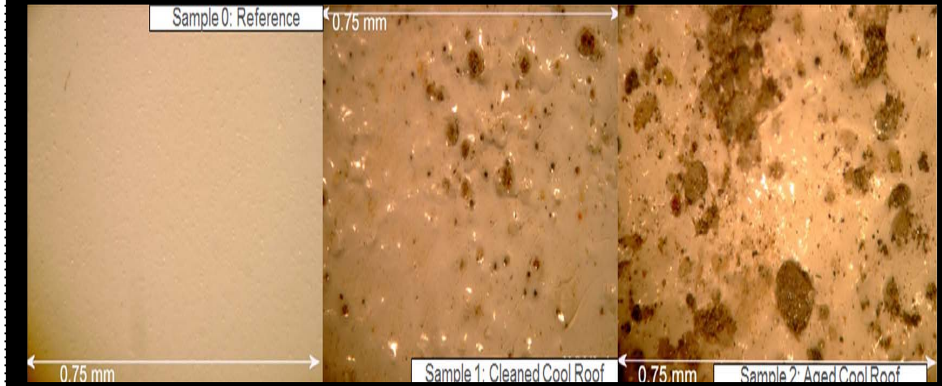
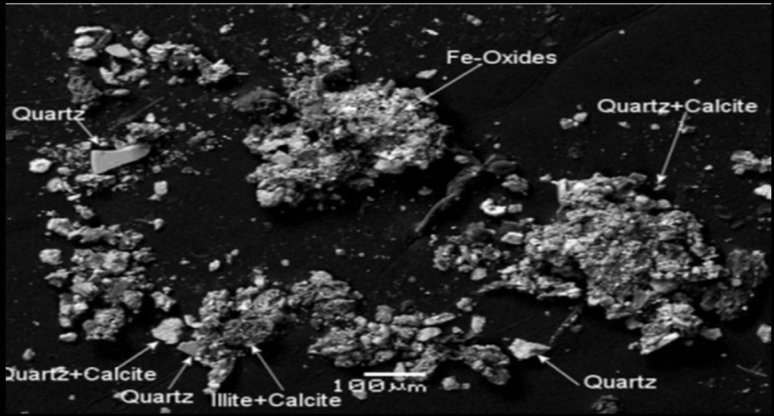
Research on Advanced Mitigation Material for the Urban Environment
Colored IR reflecting Coatings

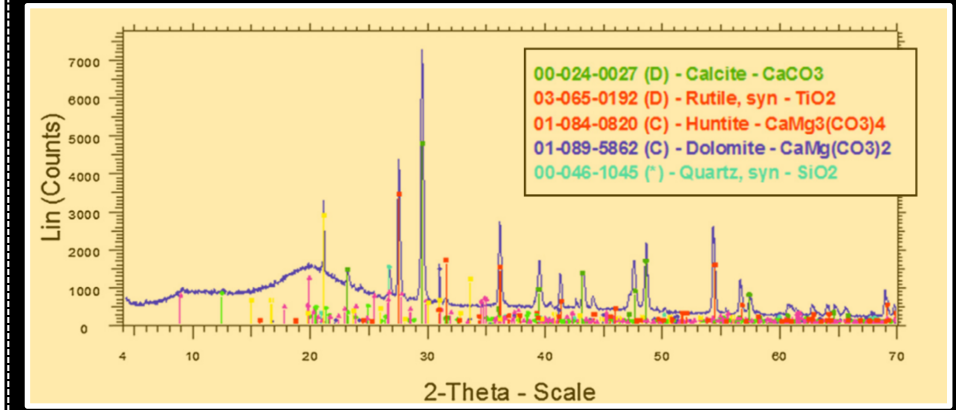
Samples from Existing Applications in Stereoscopic Microscope



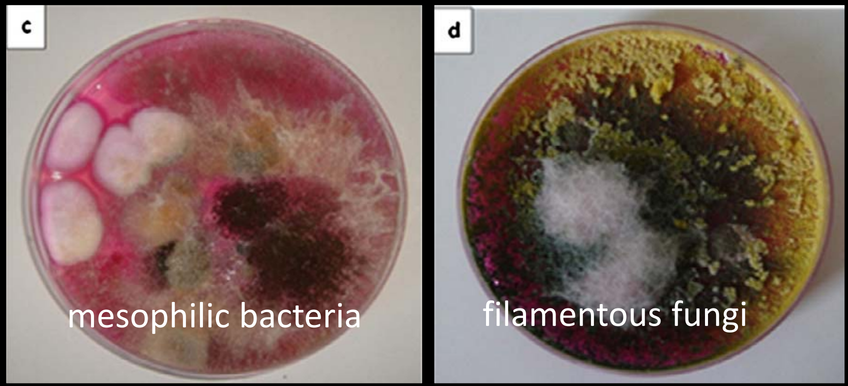
Scanning Electron Microscopy (SEM) to study the distribution of contaminants on the surface of samples



X-ray diffractometry using X-ray Powder Diffraction Spectrometer

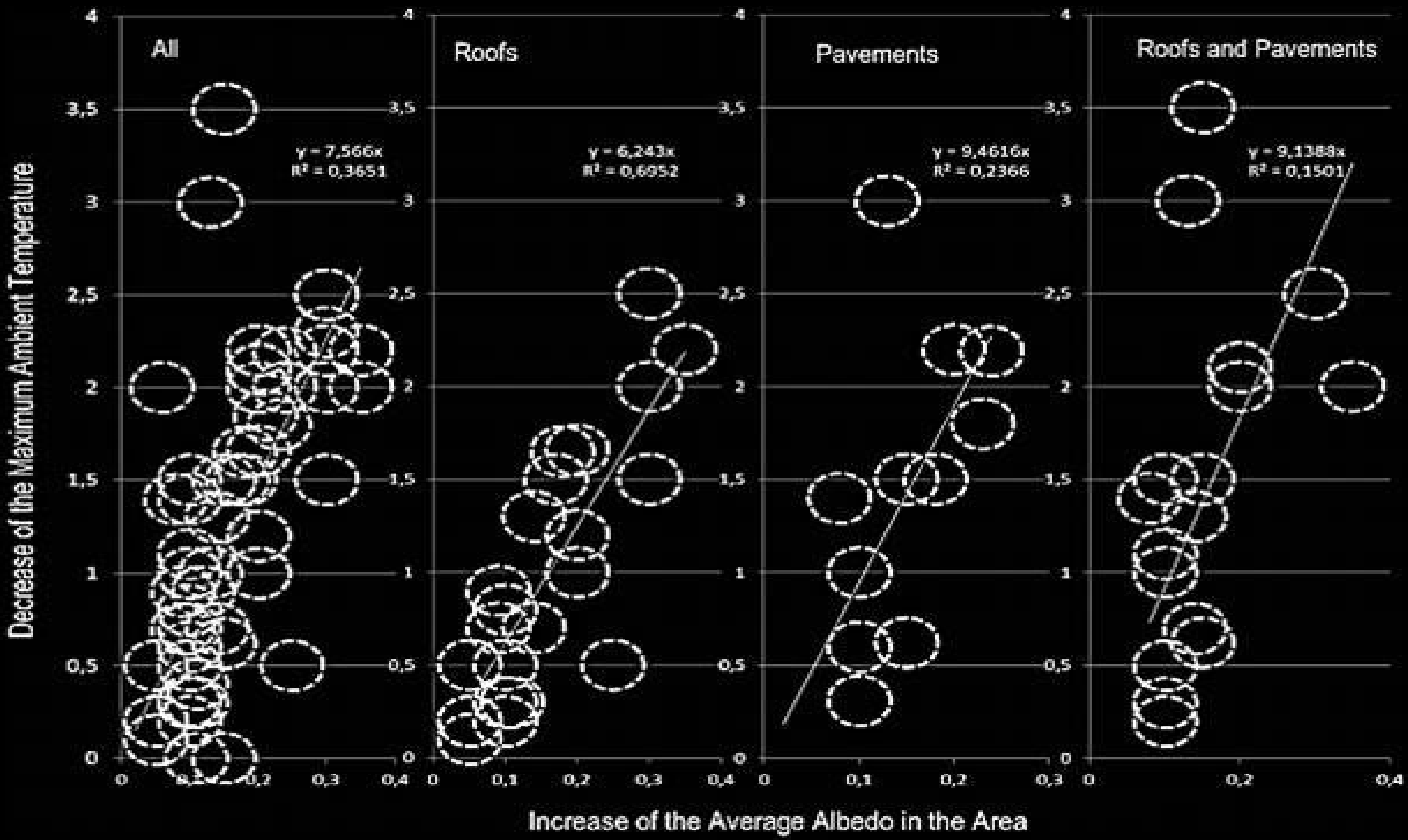


Microbiological Analysis



Source : Mastrapostoli E, Santamouris et al : On the aging of cool roofs. Measure of the optical degradation, chemical and biological analysis and assessment of the energy impact Energy and Buildings, 2015

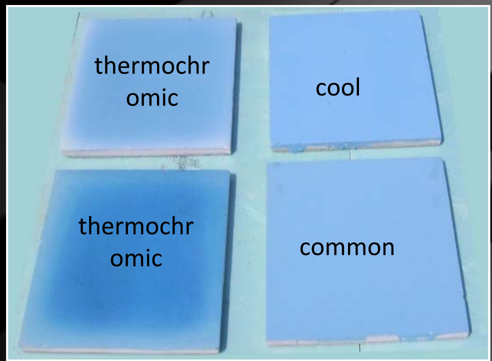
Research on Advanced Mitigation Material for the Urban Environment
Colored IR reflecting Coatings



M. Santamouris, L. Ding, F. Fiorito, P. Oldfield, Paul Osmond, R. Paolini, D. Prasad, A. Synnefa : Passive and active cooling for the outdoor built environment – Analysis and assessment of the cooling potential of mitigation technologies using performance . Solar Energy, Volume 154, 15 September 2017, Pages 14-33

Research on Advanced Mitigation Material for the Urban Environment

Thermochromic Coatings

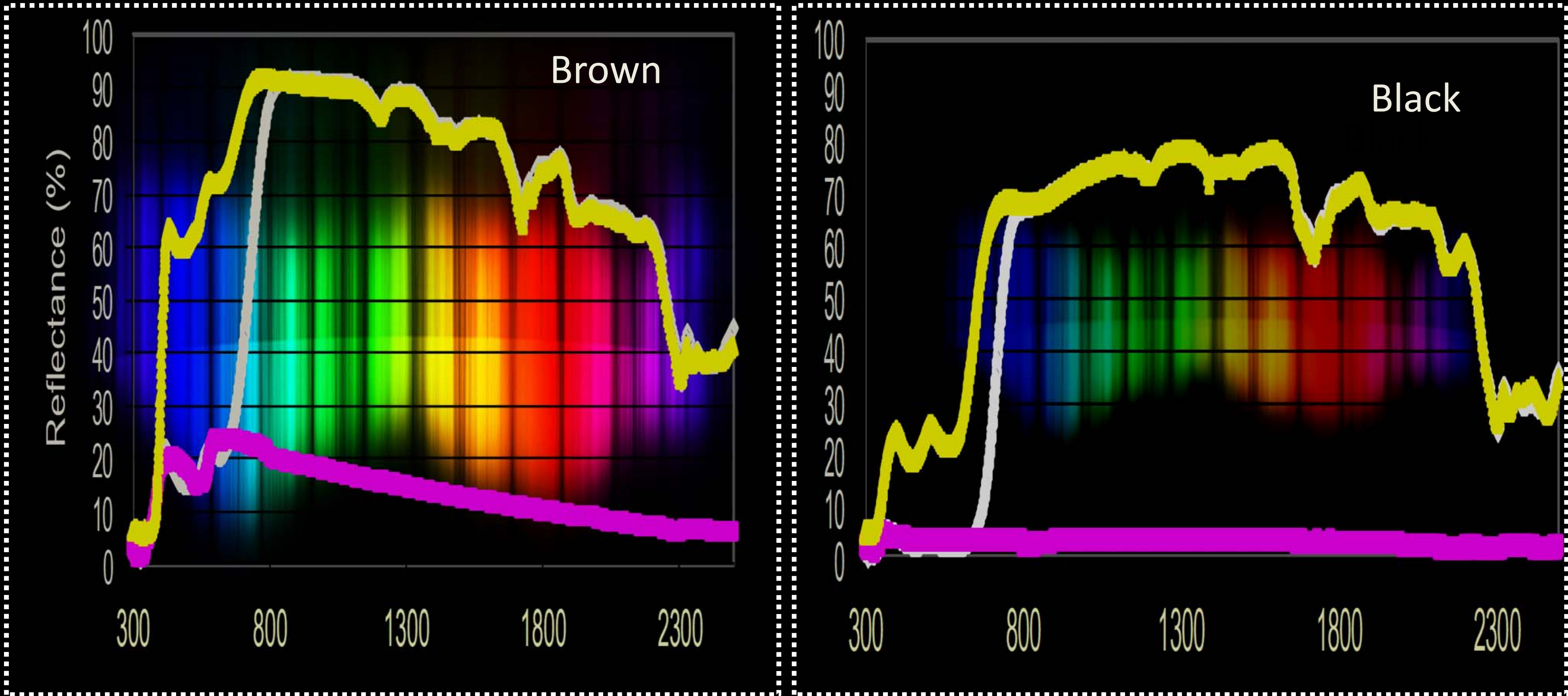


Thermochromic coatings change color as a function of the ambient temperature.

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 they may present the best performance all year round.

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

Research on Advanced Mitigation Material for the Urban Environment
Thermochromic Coatings



Thermochromic coatings present a high reflectivity both in the visible and infrared spectrum, while present very strong absorption in the near-ultraviolet range of the spectrum.

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

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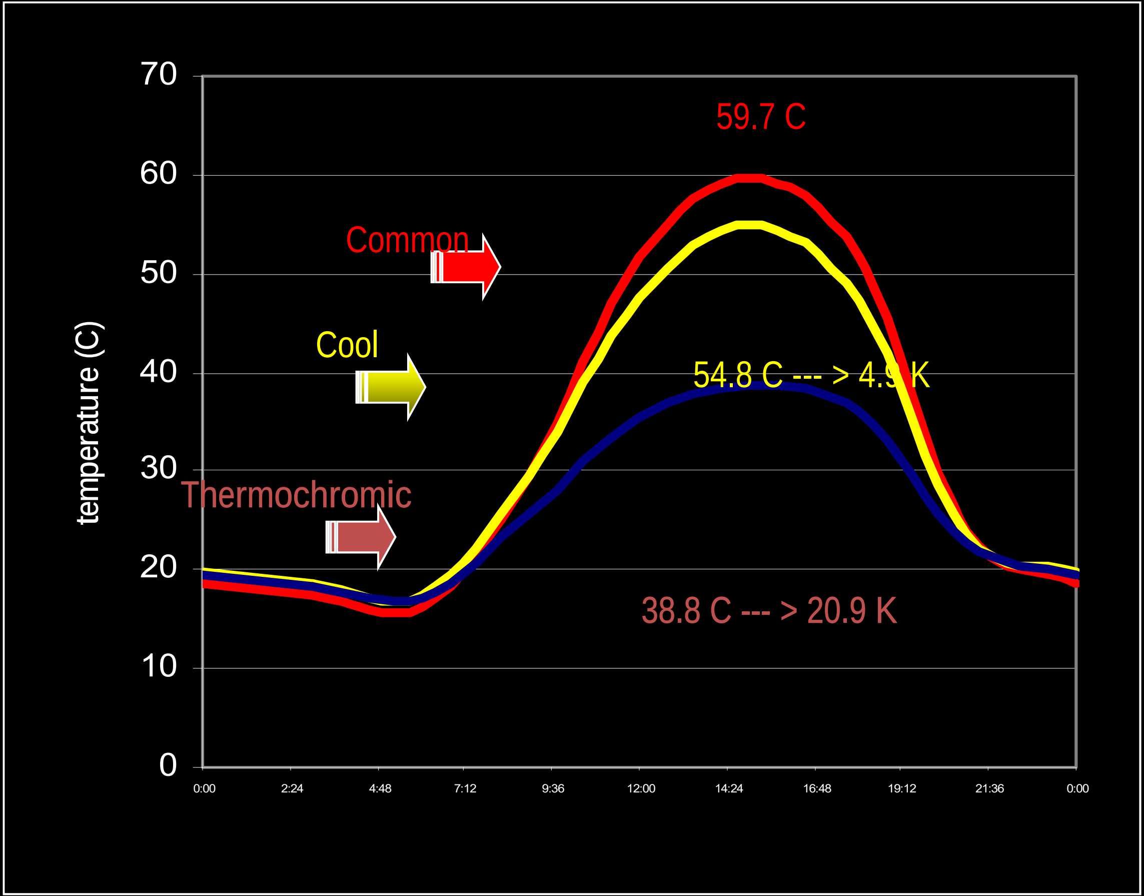
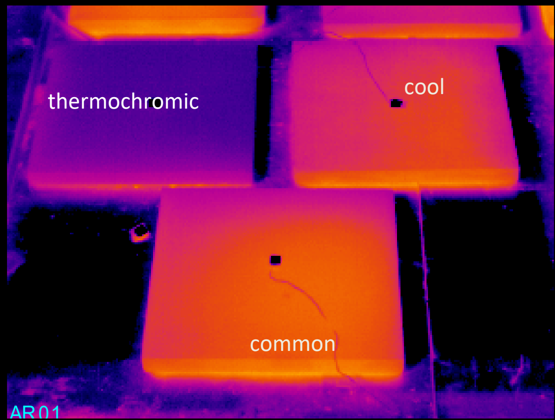


Black



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

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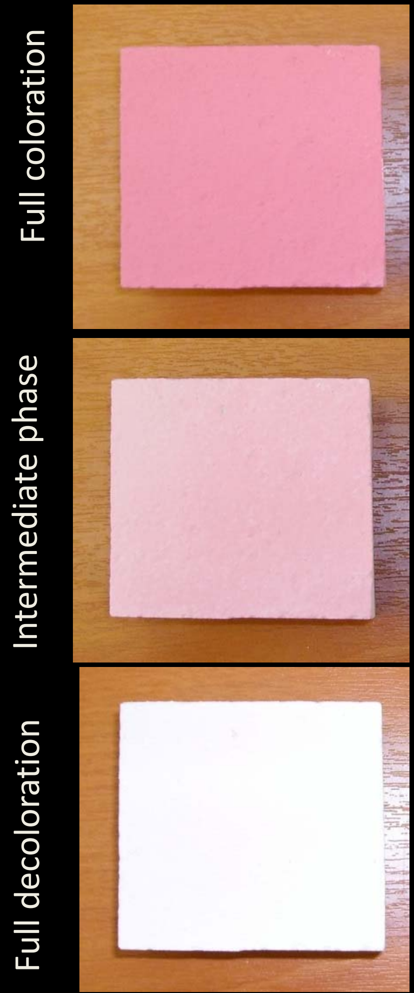
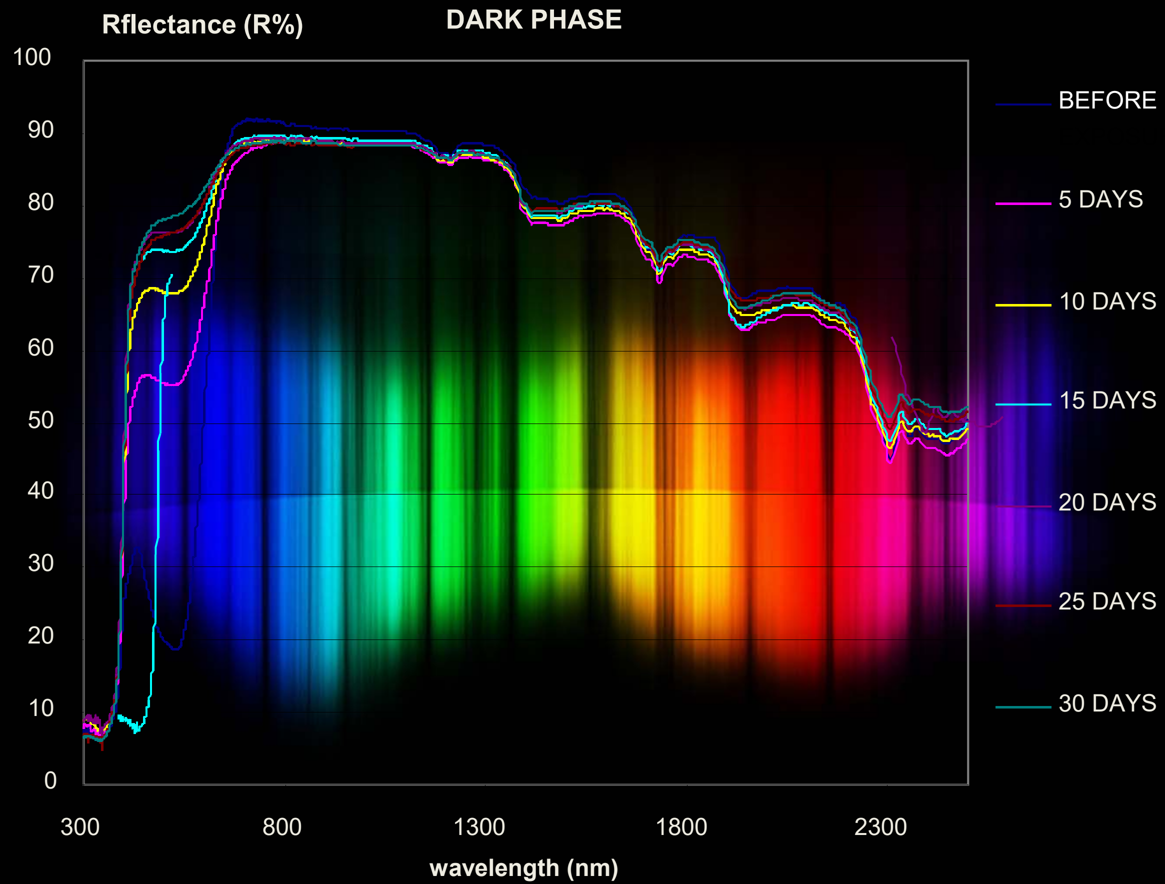
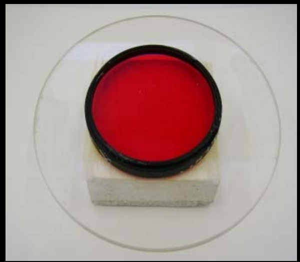
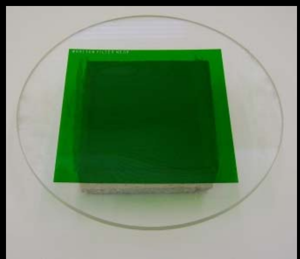


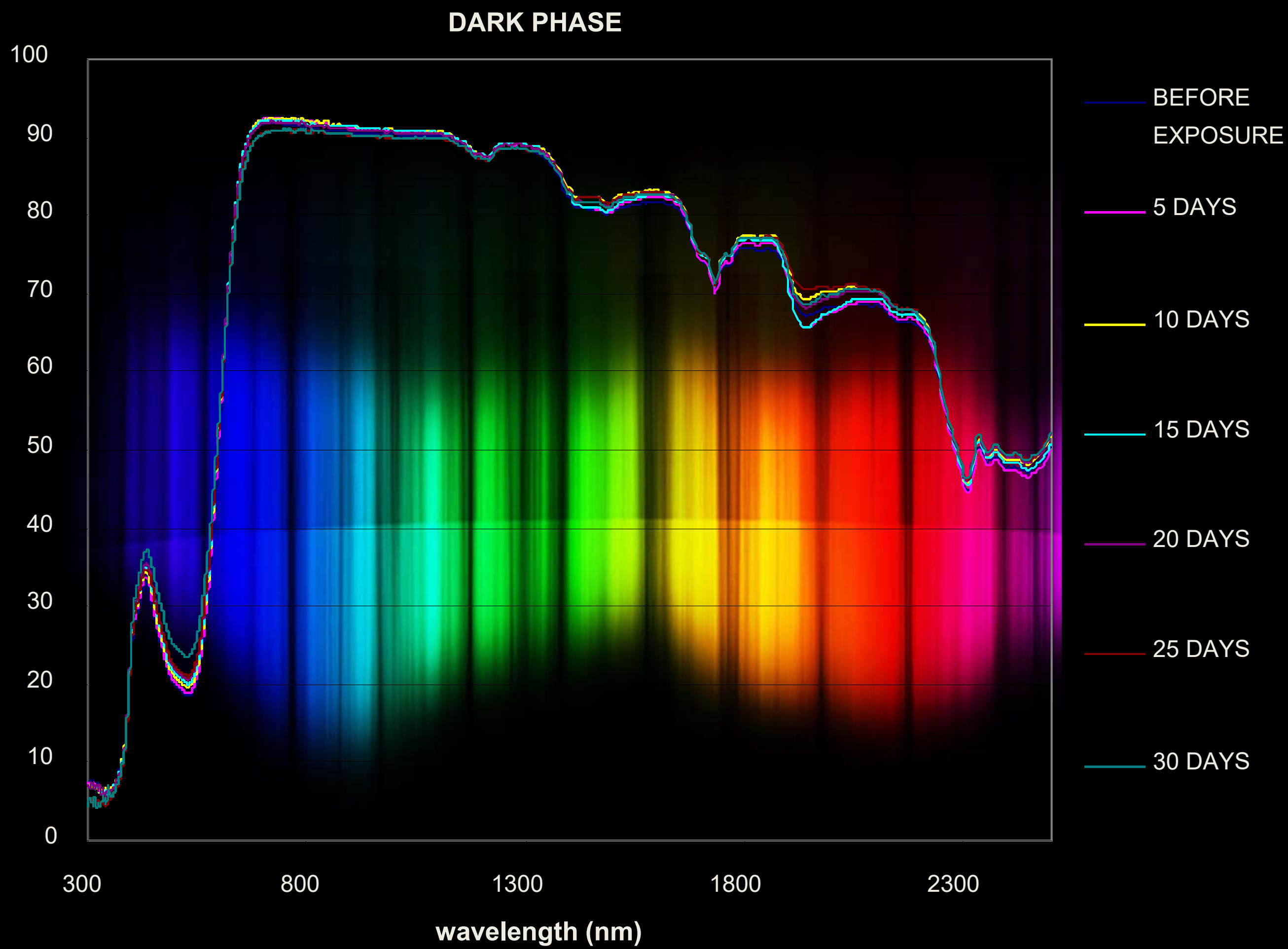


Theoni Karlessi and Mat Santamouris : Improving the performance of thermochromic coatings with the use of UV and optical filters tested under accelerated aging conditions, J. low Carbon Technologies, 2015,

Research on Advanced Mitigation Material for the Urban Environment
Thermochromic Coatings







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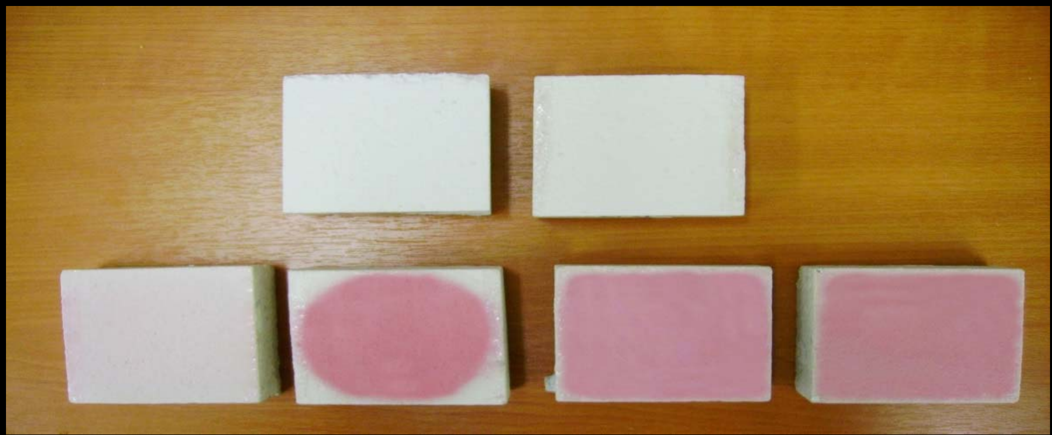
Research on Advanced Mitigation Material for the Urban Environment
Thermochromic Coatings

Samples on 5th day of exposure

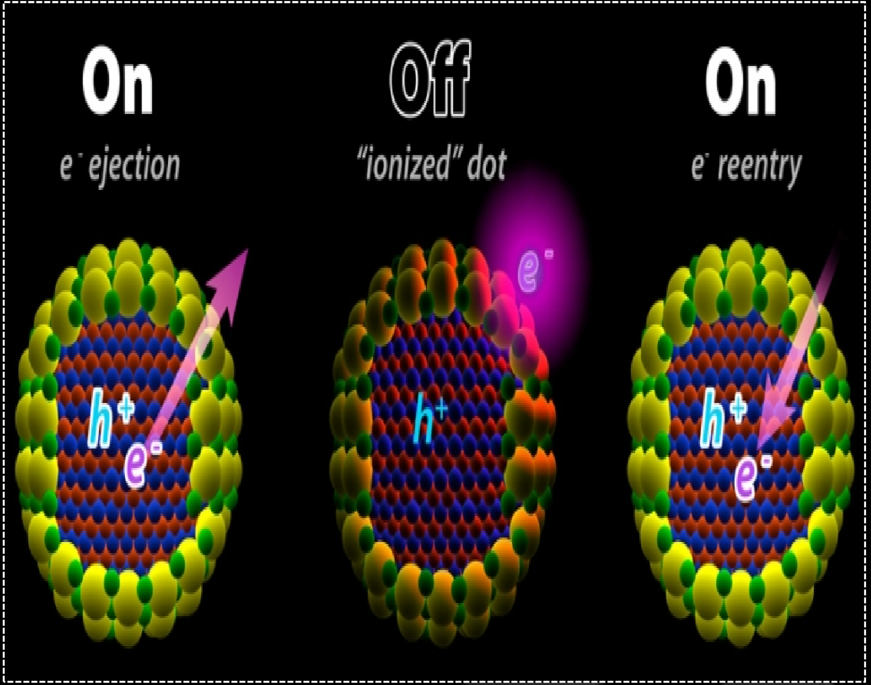


Samples on 30th day of exposure

Theoni Karlessi and Mat Santamouris : Improving the performance of thermochromic coatings with the use of UV and optical filters tested under accelerated aging conditions, J. low Carbon Technologies, 2015,

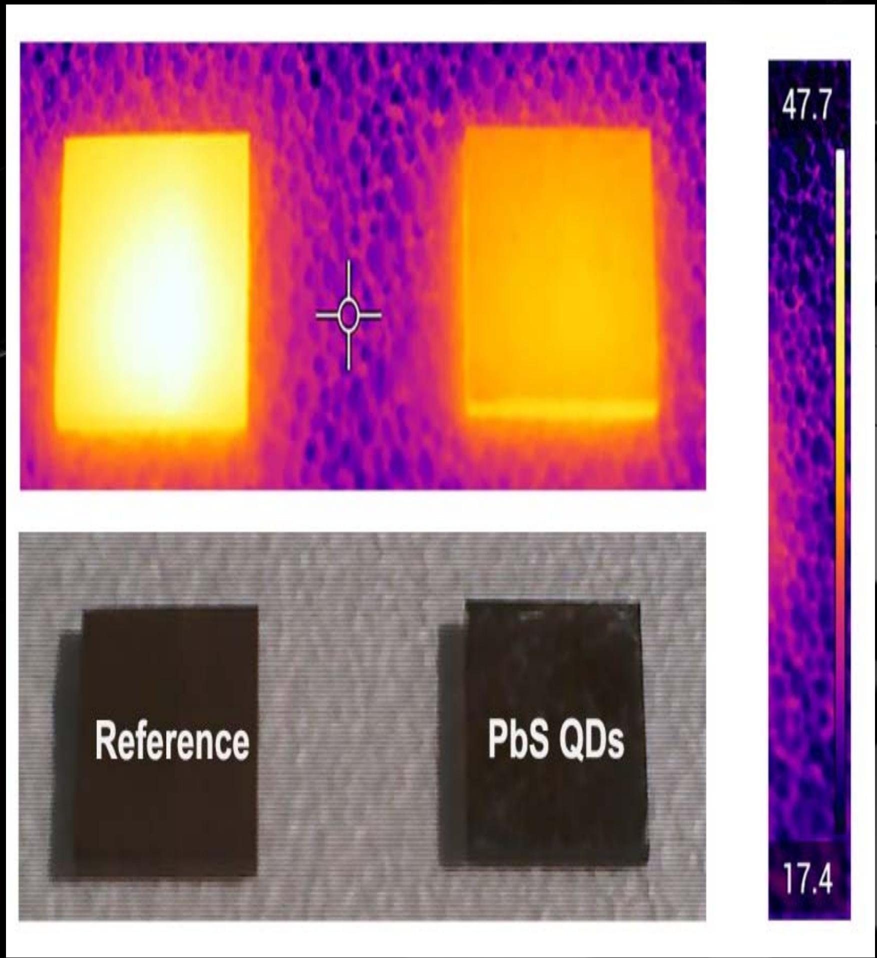
Research on Advanced Mitigation Material for the Urban Environment
Use of Quantum Dots for Mitigation ?

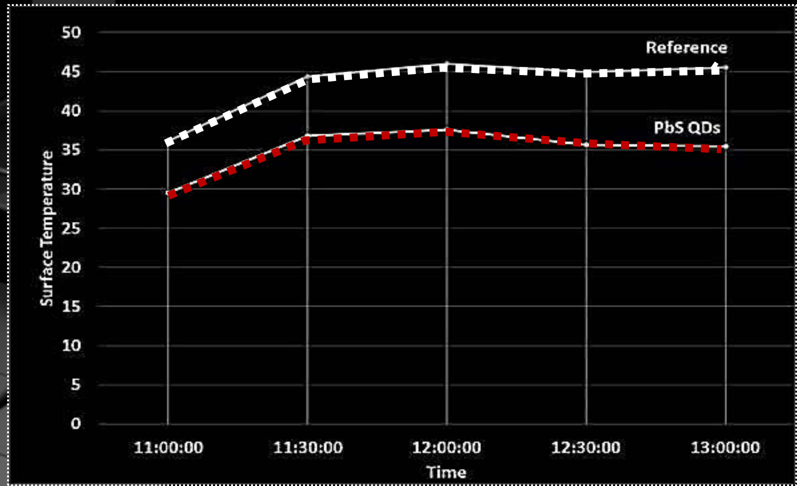
Quantum dots (QD) are very small semiconductor particles, only several nanometers in size, so small that their optical and electronic properties differ from those of larger particles. They are a central theme in nanotechnology. Many types of quantum dot will emit light of specific frequencies if electricity or light is applied to them, and these frequencies can be precisely tuned by changing the dots' size, shape and material, giving rise to many applications.

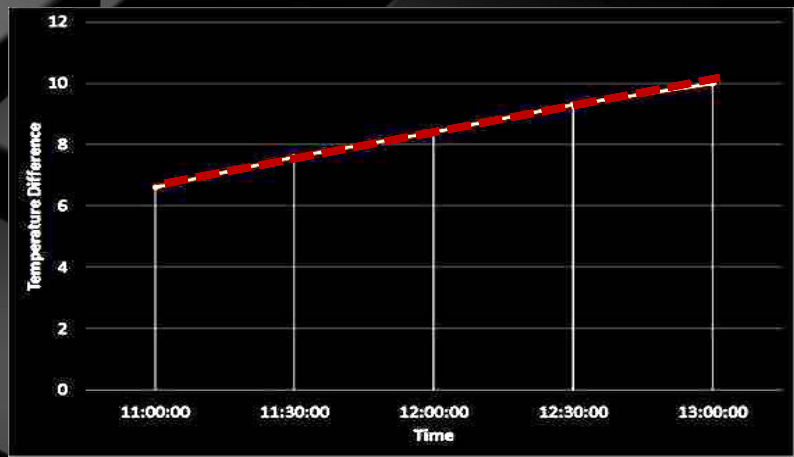


M. Santamouris and S. Garshasbi : Innovative New Generation Mitigation Technologies, SET 2018

Research on Advanced Mitigation Material for the Urban Environment
Use of Quantum Dots for Mitigation ?



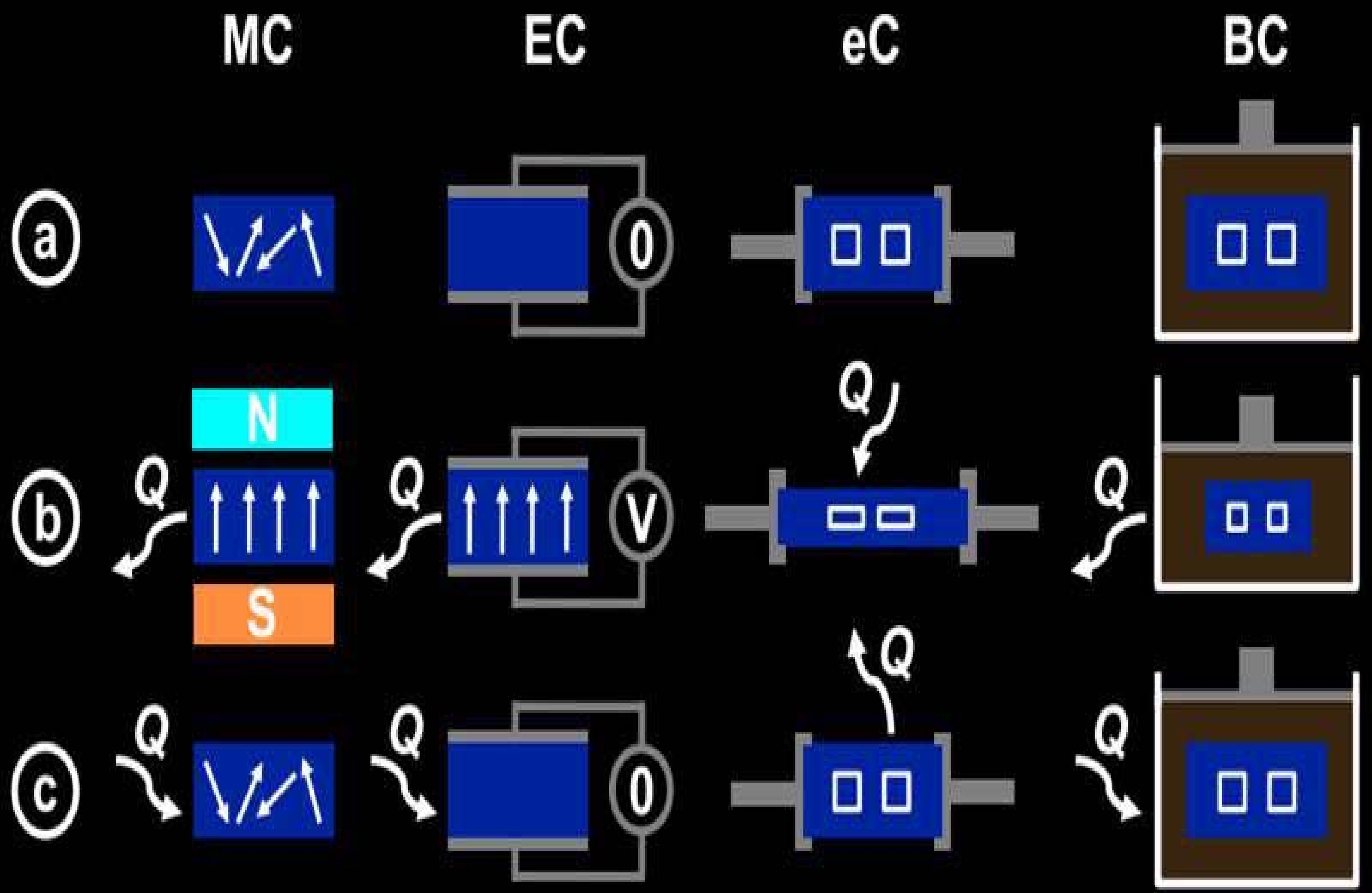




M. Santamouris and S. Garshasbi : Innovative New Generation Mitigation Technologies, SET 2018

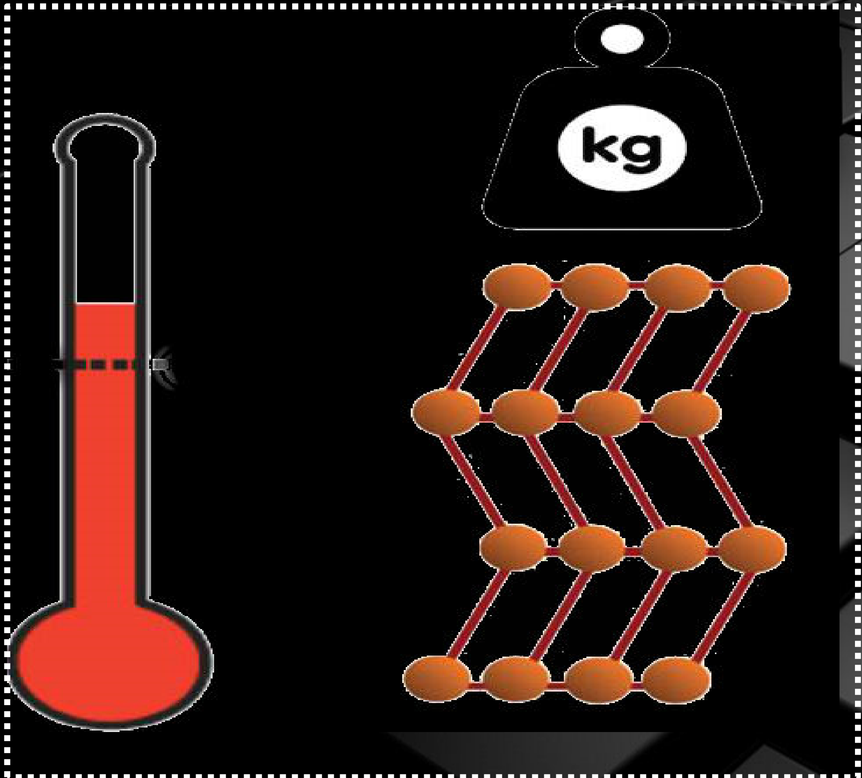
Research on Advanced Mitigation Material for the Urban Environment

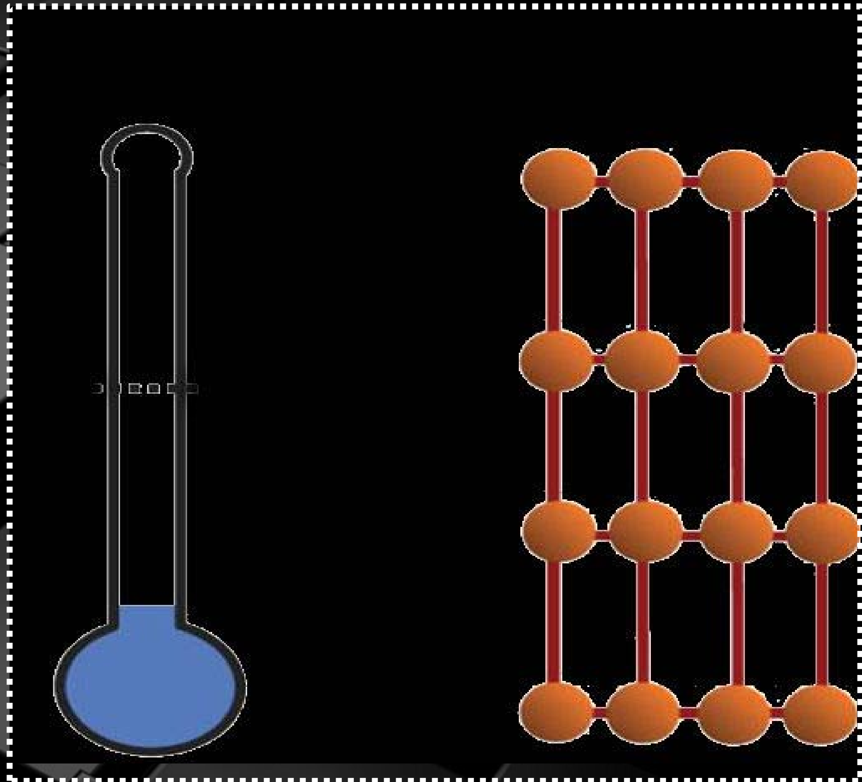
Use of Solid State Materials for Cooling ?



Research on Advanced Mitigation Material for the Urban Environment
Use of Elastocaloric Materials for Cooling ?

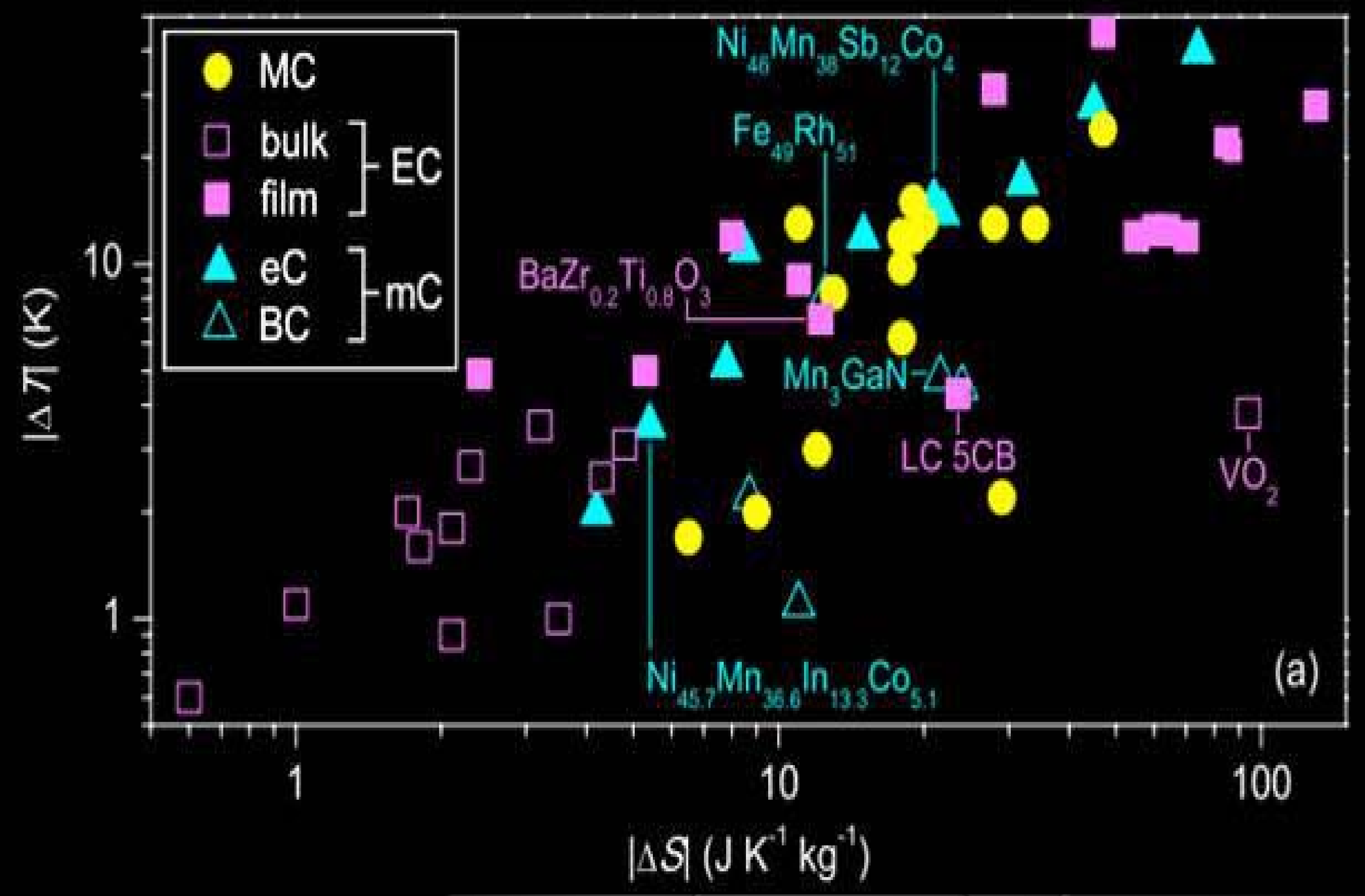
Elastocaloric materials are solids capable of stress-induced reversible phase transformations during which latent heat is released or absorbed. The elastocaloric effect occurs when stress is applied or removed, and a phase transformation is induced. As a result of the entropy difference between the two co-existing phases, the material heats up or cools down. A good elastocaloric material must exhibit a large latent heat, a large adiabatic temperature change, good thermal conductivity, long fatigue life, and low cost. Shape memory polymers can also exhibit elastocaloric effect.



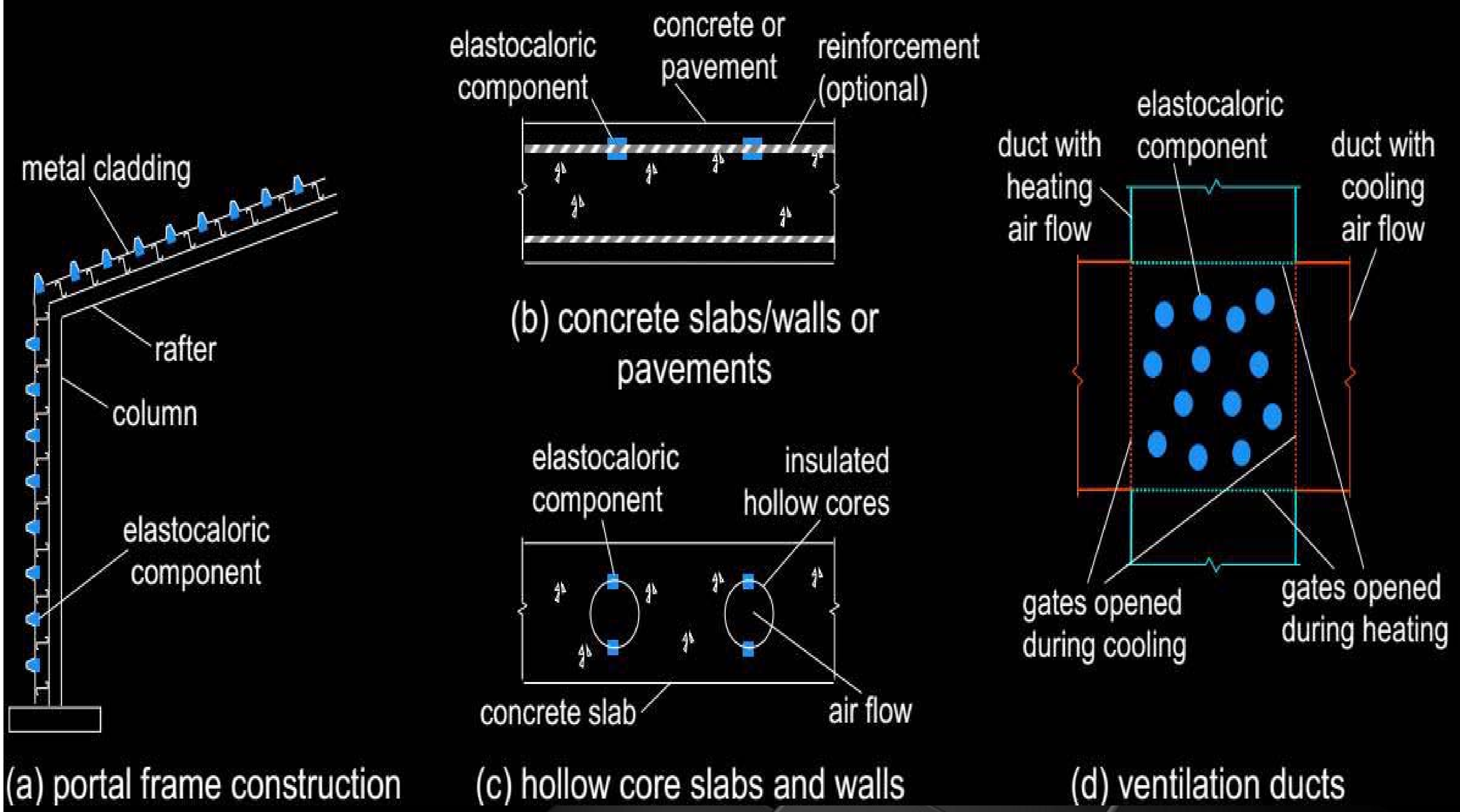


GL Ranzi and M. Santamouris : Development of Advanced Elastocaloric Materials for Building Applications , Discovery Project, ARC, 2018

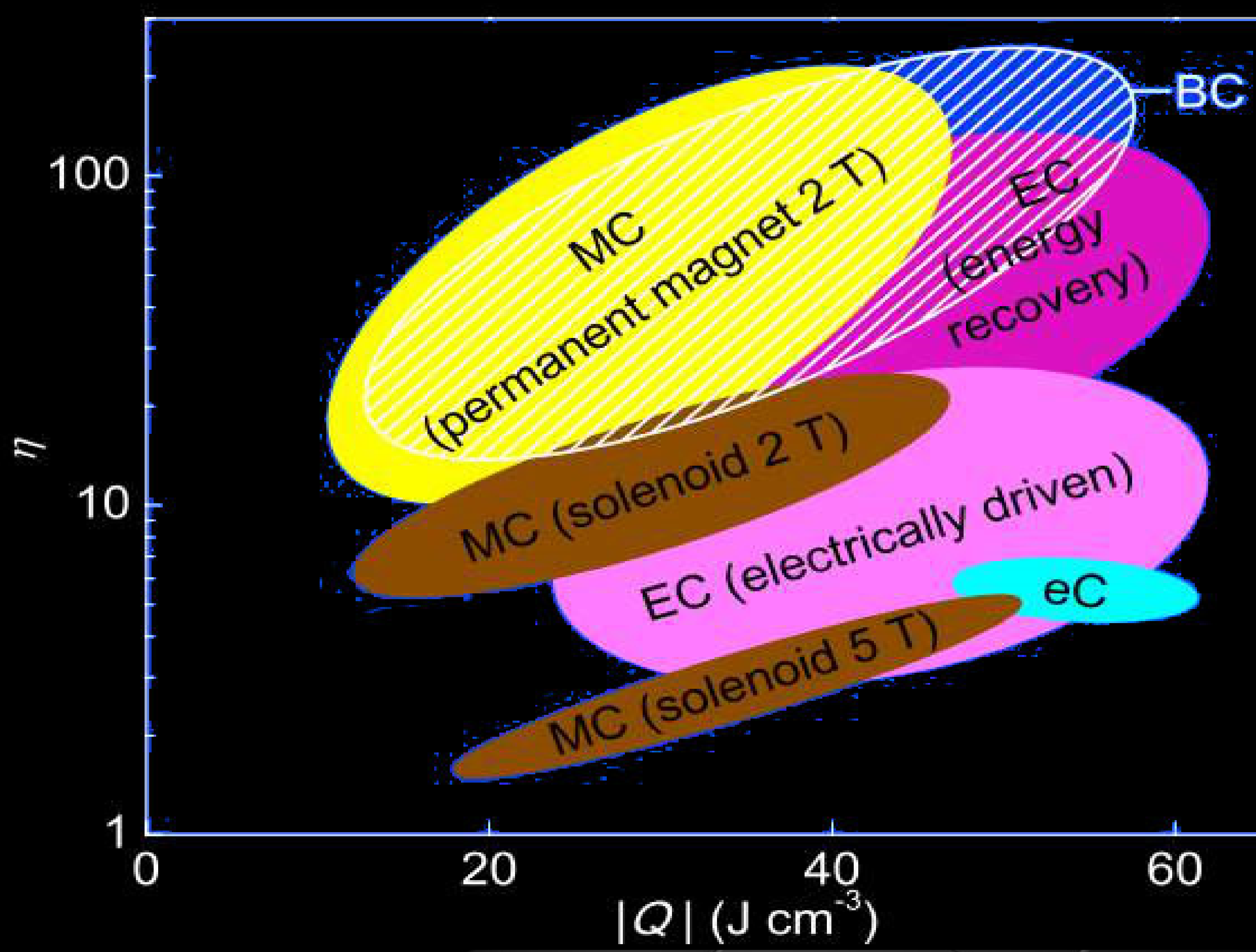
Research on Advanced Mitigation Material for the Urban Environment
Use of Solid State Materials for Cooling ?



Research on Advanced Mitigation Material for the Urban Environment
Use of Elastocaloric Materials for Cooling ?

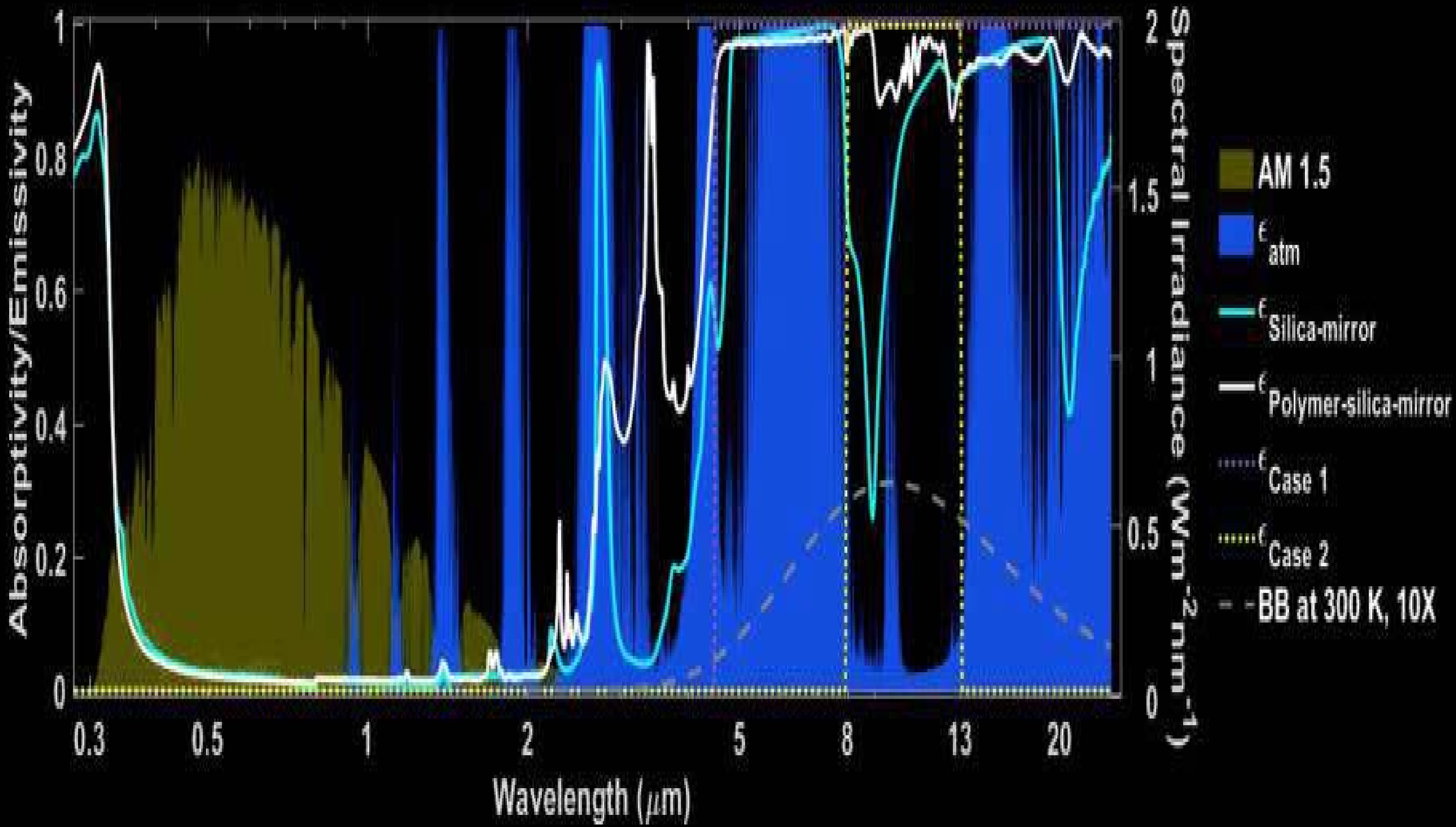


Research on Advanced Mitigation Material for the Urban Environment
Use of Solid State Materials for Cooling ?

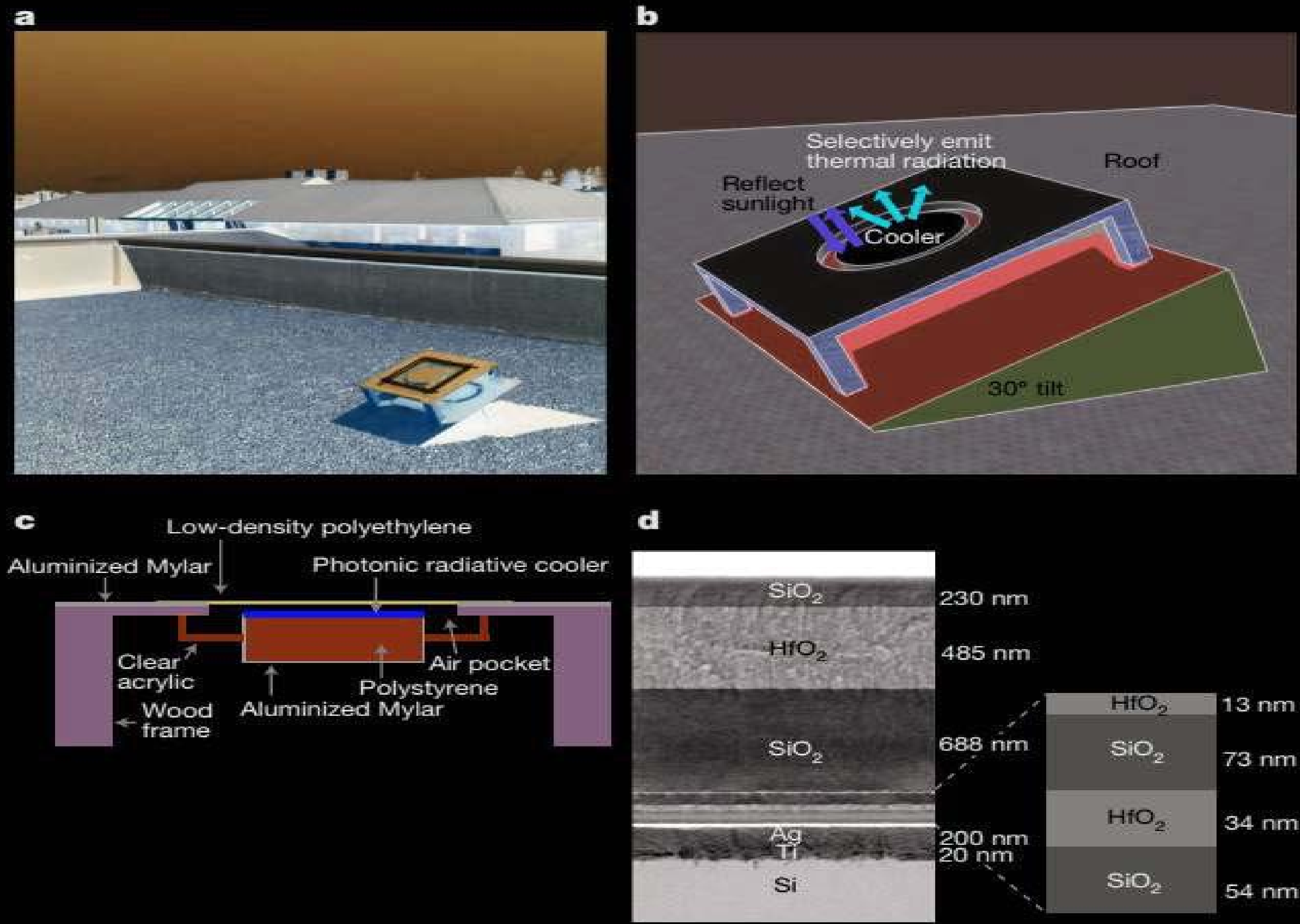


Research on Advanced Mitigation Material for the Urban Environment

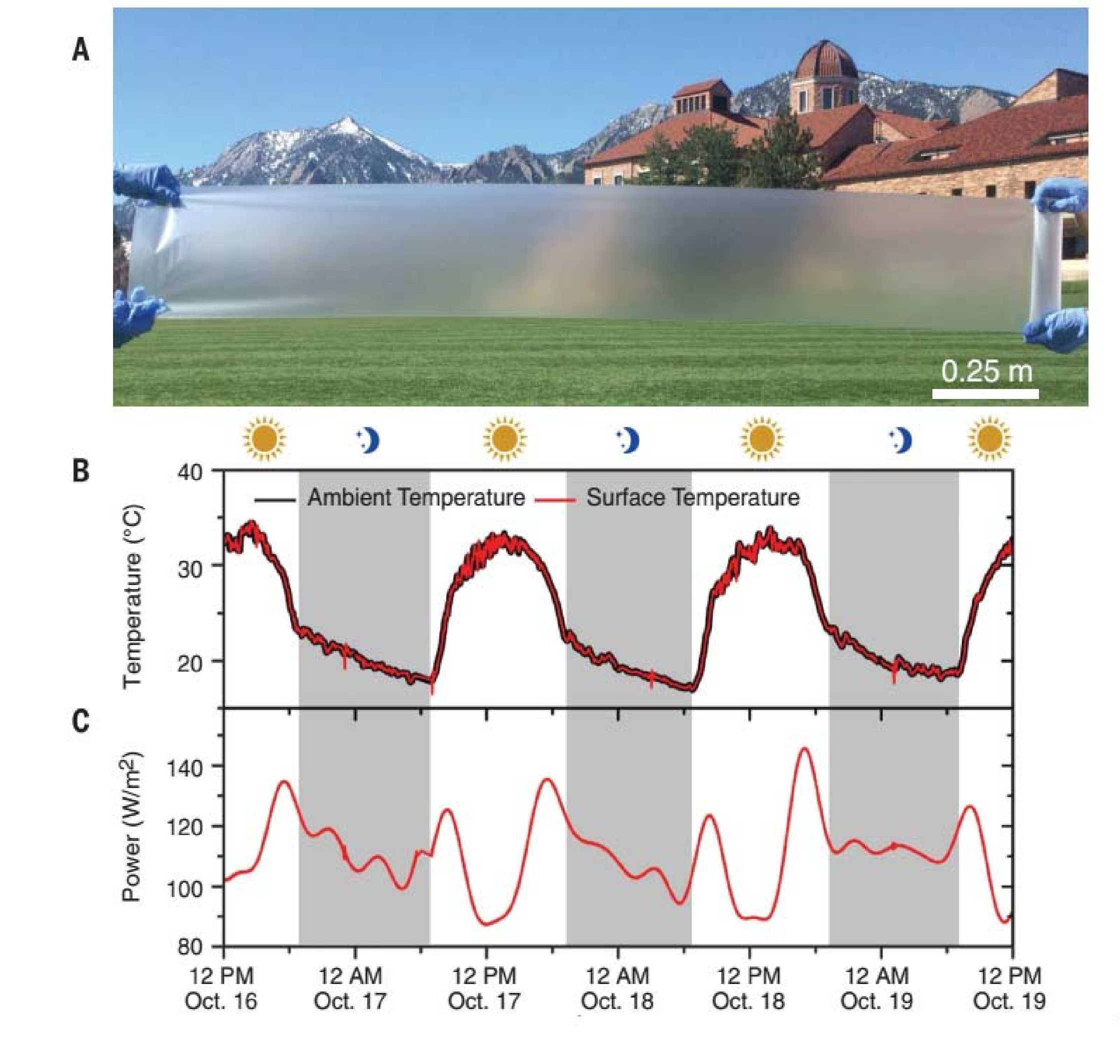
Use of Highly Radiative Materials – Below the Ambient Temperature ?



Research on Advanced Mitigation Material for the Urban Environment
Use of Highly Radiative Materials – Below the Ambient Temperature ?



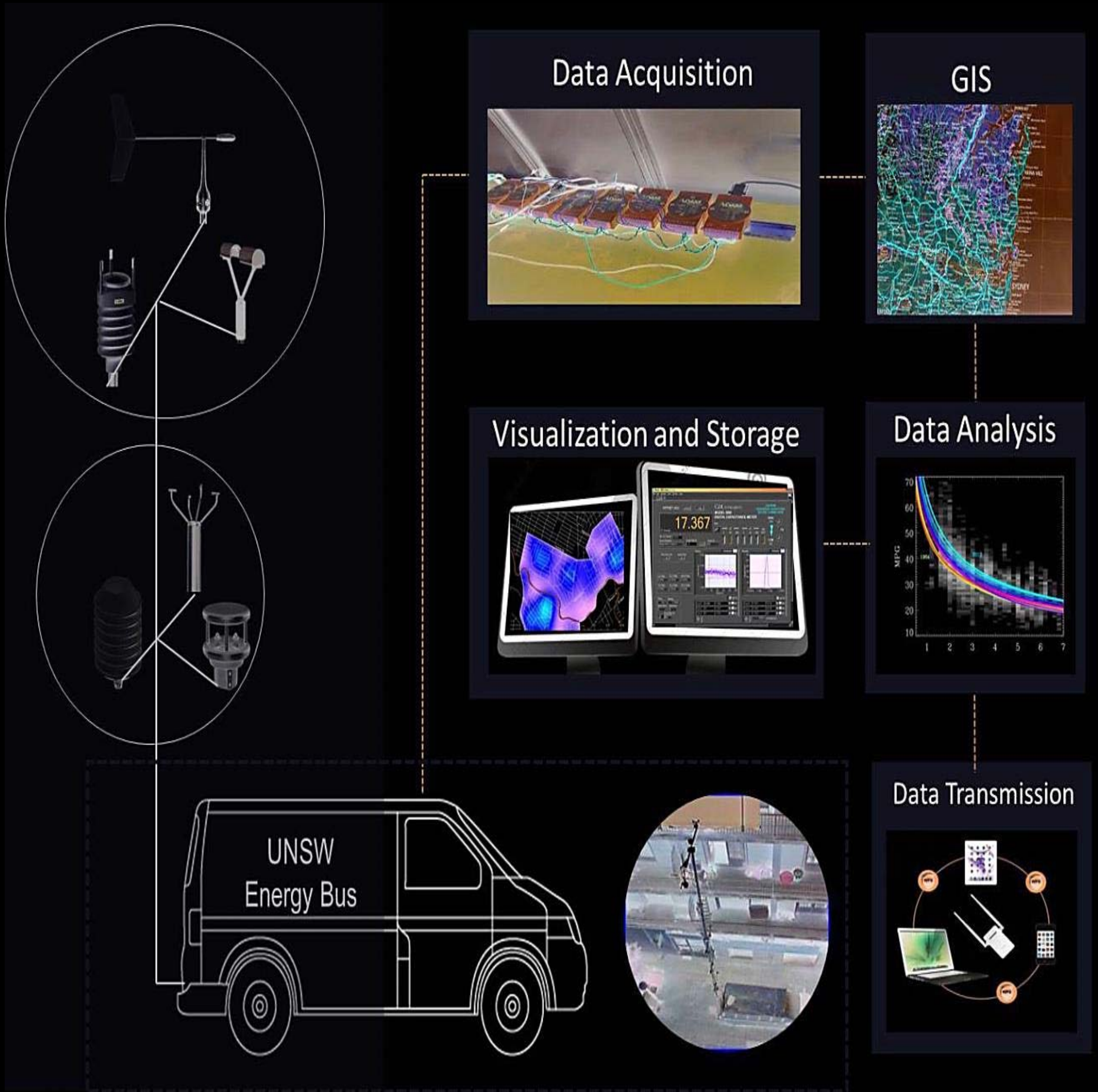
Research on Advanced Mitigation Material for the Urban Environment
Use of Highly Radiative Materials – Below the Ambient Temperature ?

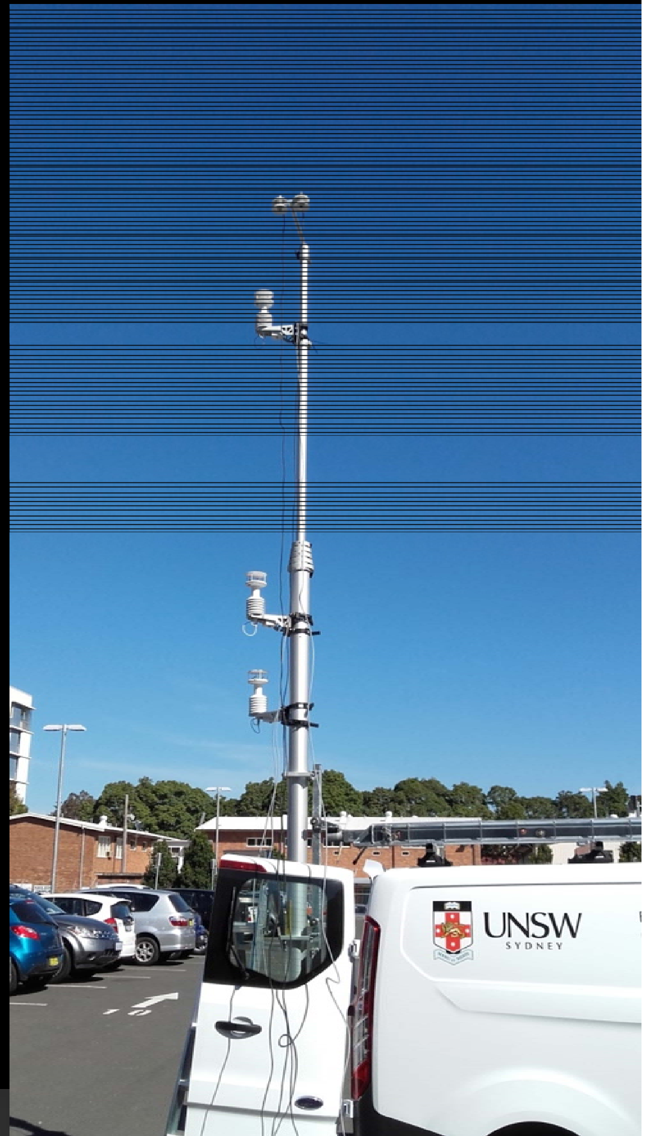


Passive radiative cooling draws heat from surfaces and radiates it into space as infrared radiation to which the atmosphere is transparent. However, the energy density mismatch between solar irradiance and the low infrared radiation flux from a near-ambient-temperature surface requires materials that strongly emit thermal energy and barely absorb sunlight. We embedded resonant polar dielectric microspheres randomly in a polymeric matrix, resulting in a meta-material that is fully transparent to the solar spectrum while having an infrared emissivity greater than 0.93 across the atmospheric window. When backed with a silver coating, the metamaterial shows a noontime radiative cooling power of 93 watts per square meter under direct sunshine.

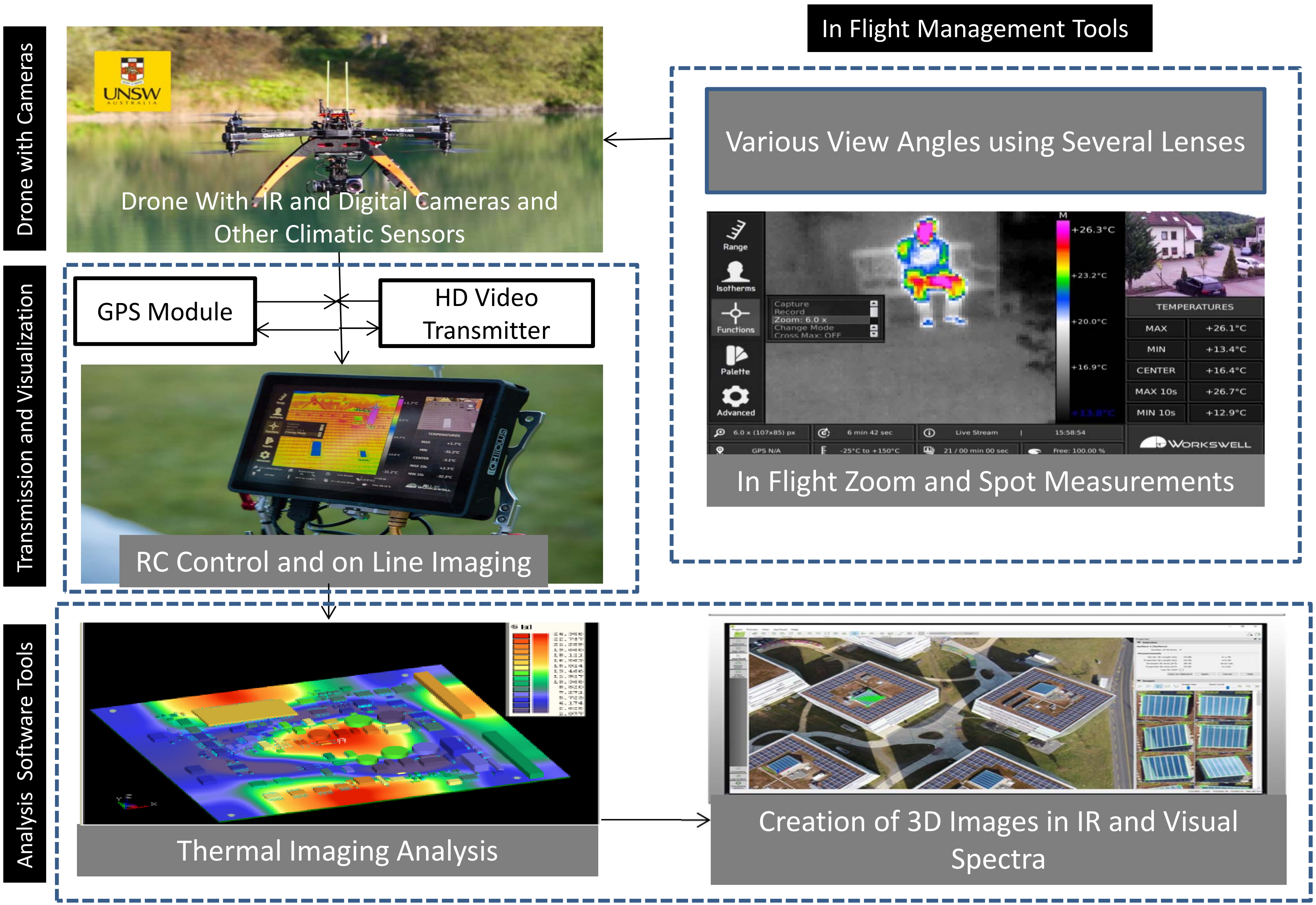
Zhai et al., Science 355, 1062–1066 (2017) 10 March 2017

On Field Experiments – Real Large Scale Case Studies

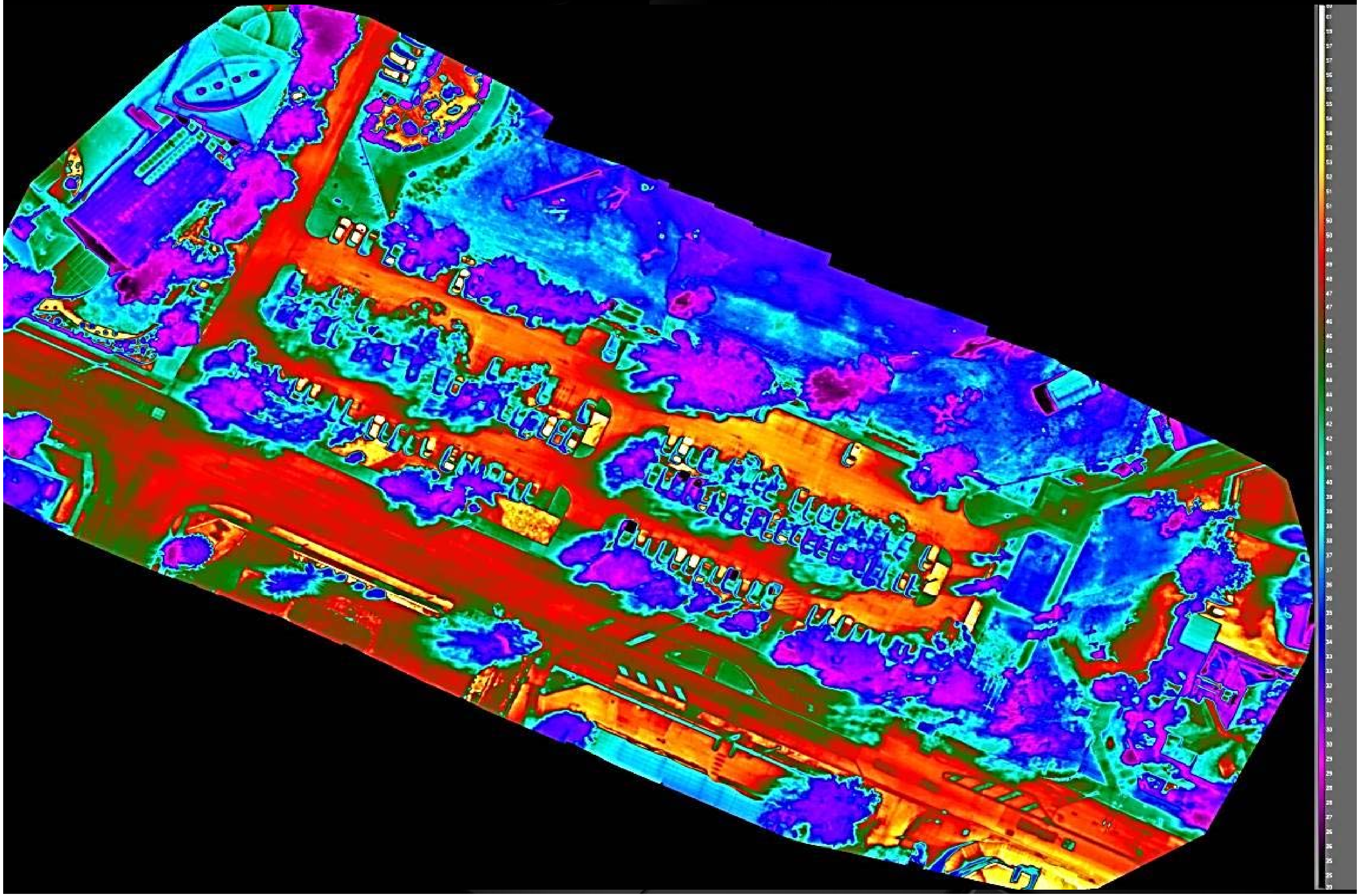


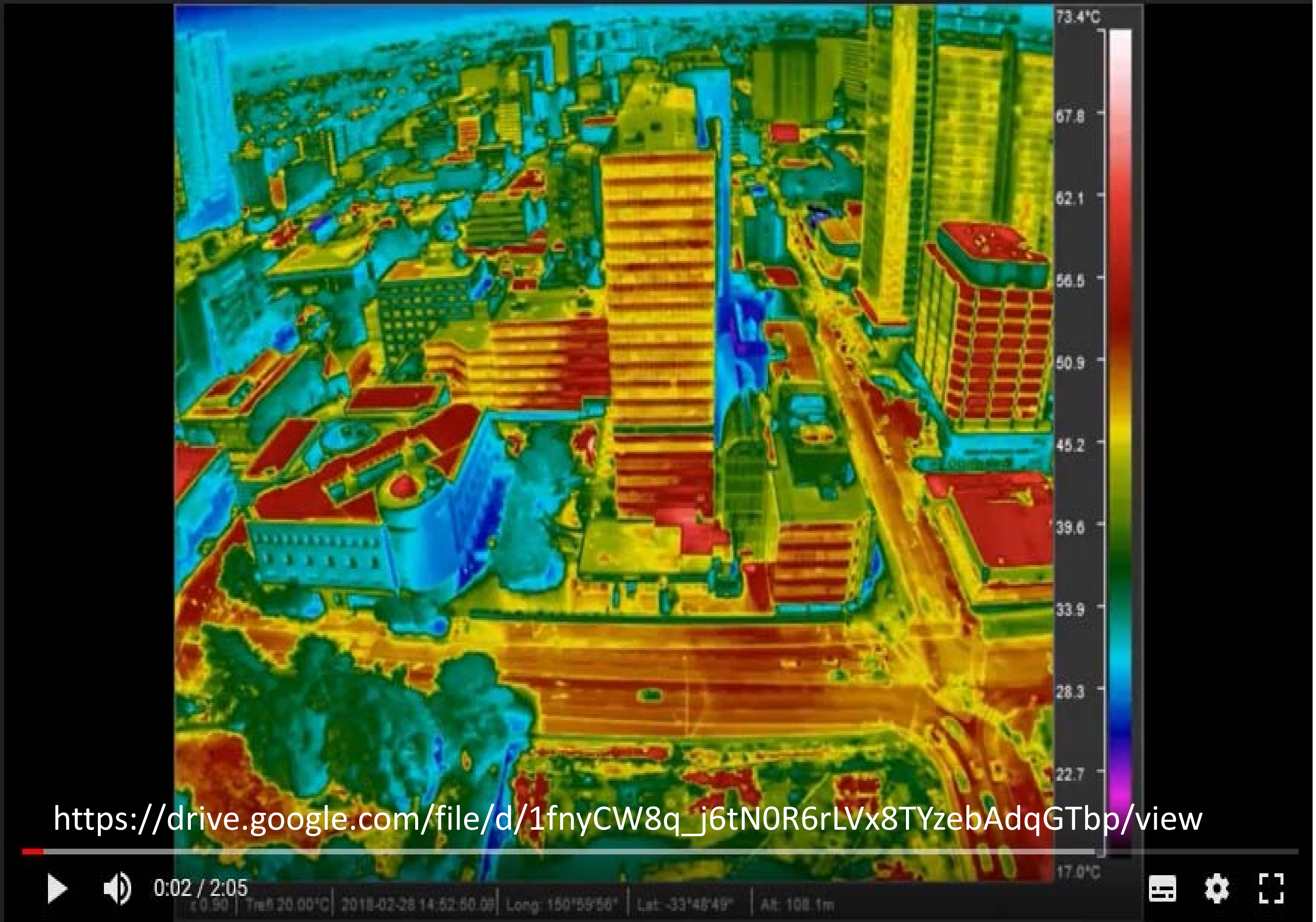


On Field Experiments – Real Large Scale Case Studies



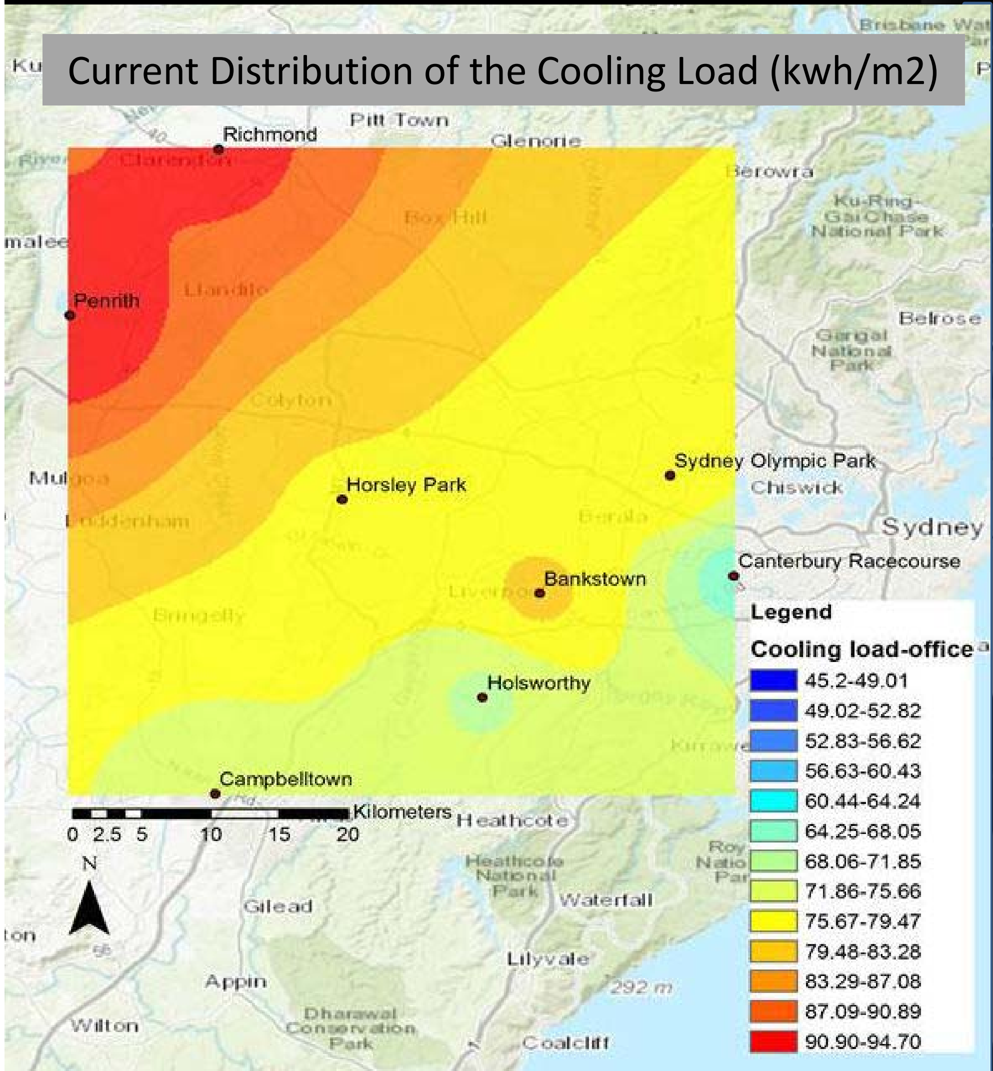
On Field Experiments – Real Large Scale Case Studies

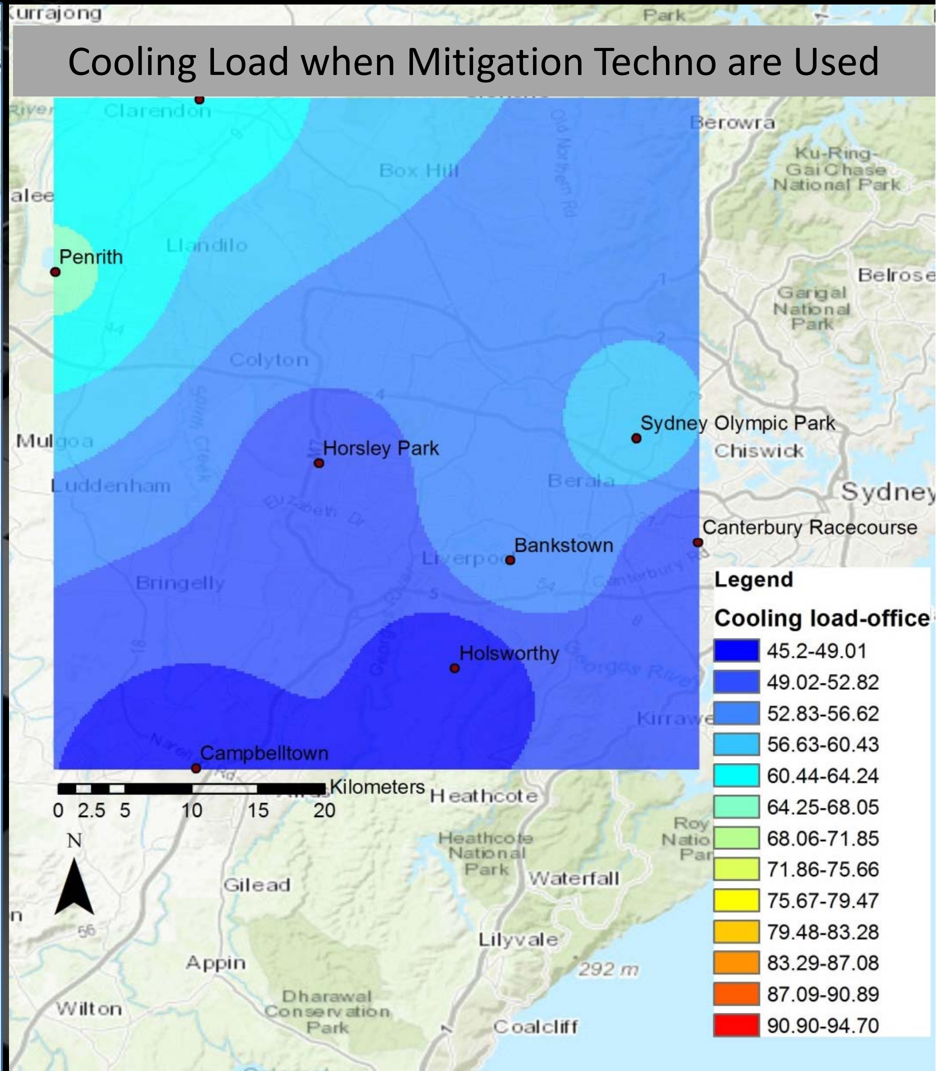




https://drive.google.com/file/d/1fnyCW8q_j6tN0R6rLVx8TYzebAdqGTbp/view

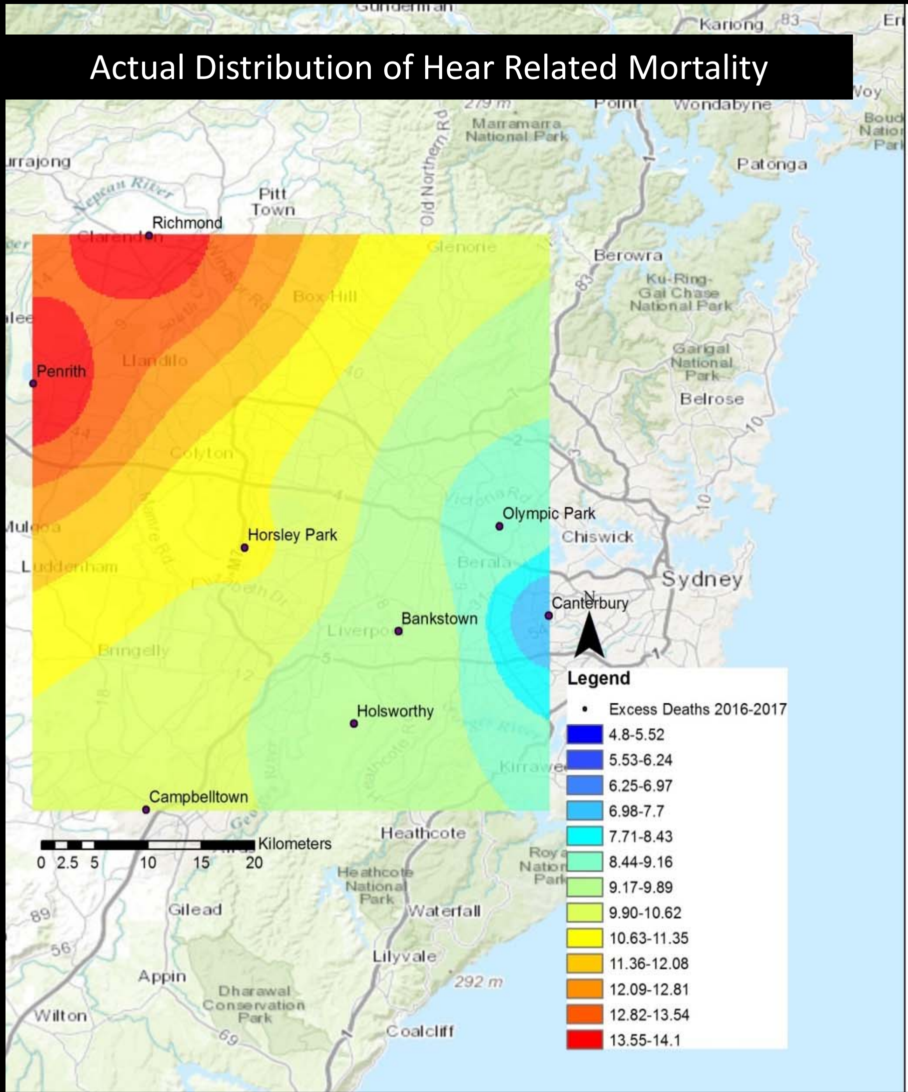
Impact on Energy – Real Large Scale Case Studies

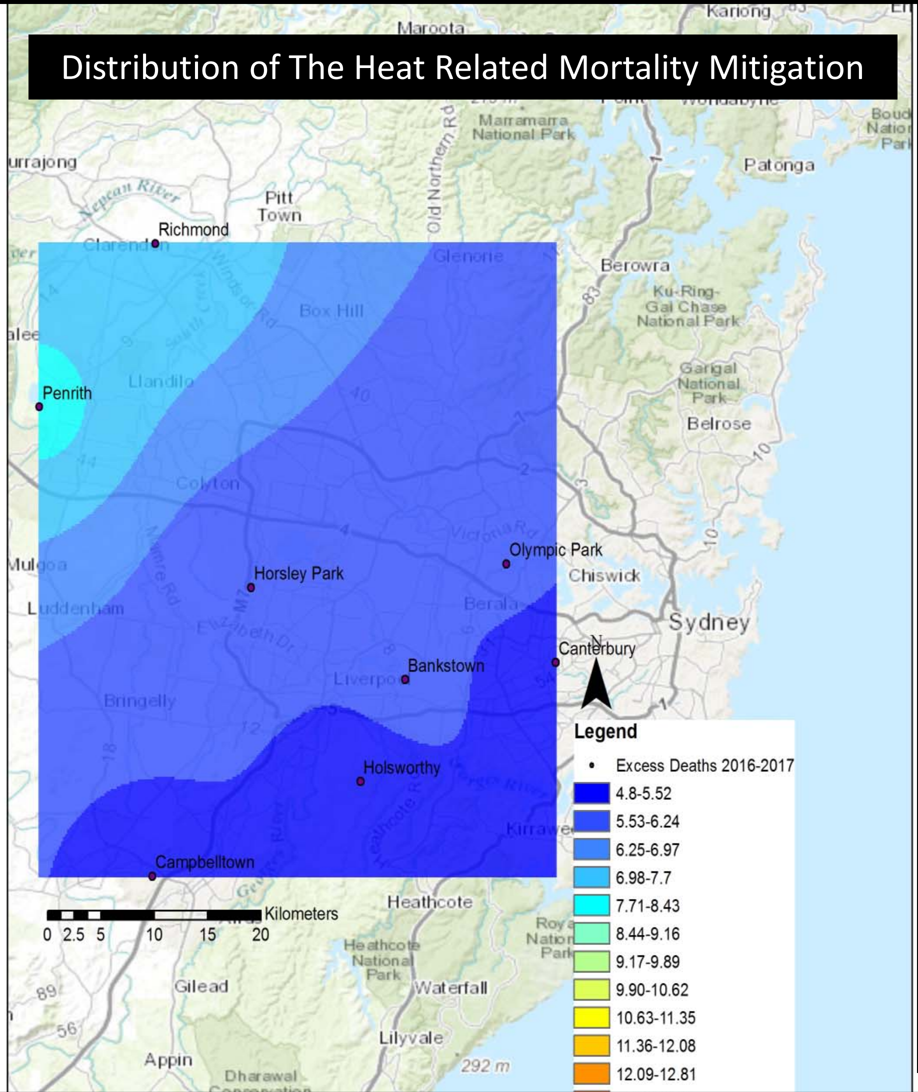




Source : M. Santamouris : Heat Mitigation Study Western Sydney. Sydney Water, 2017

Impact on Health – Real Large Scale Case Studies





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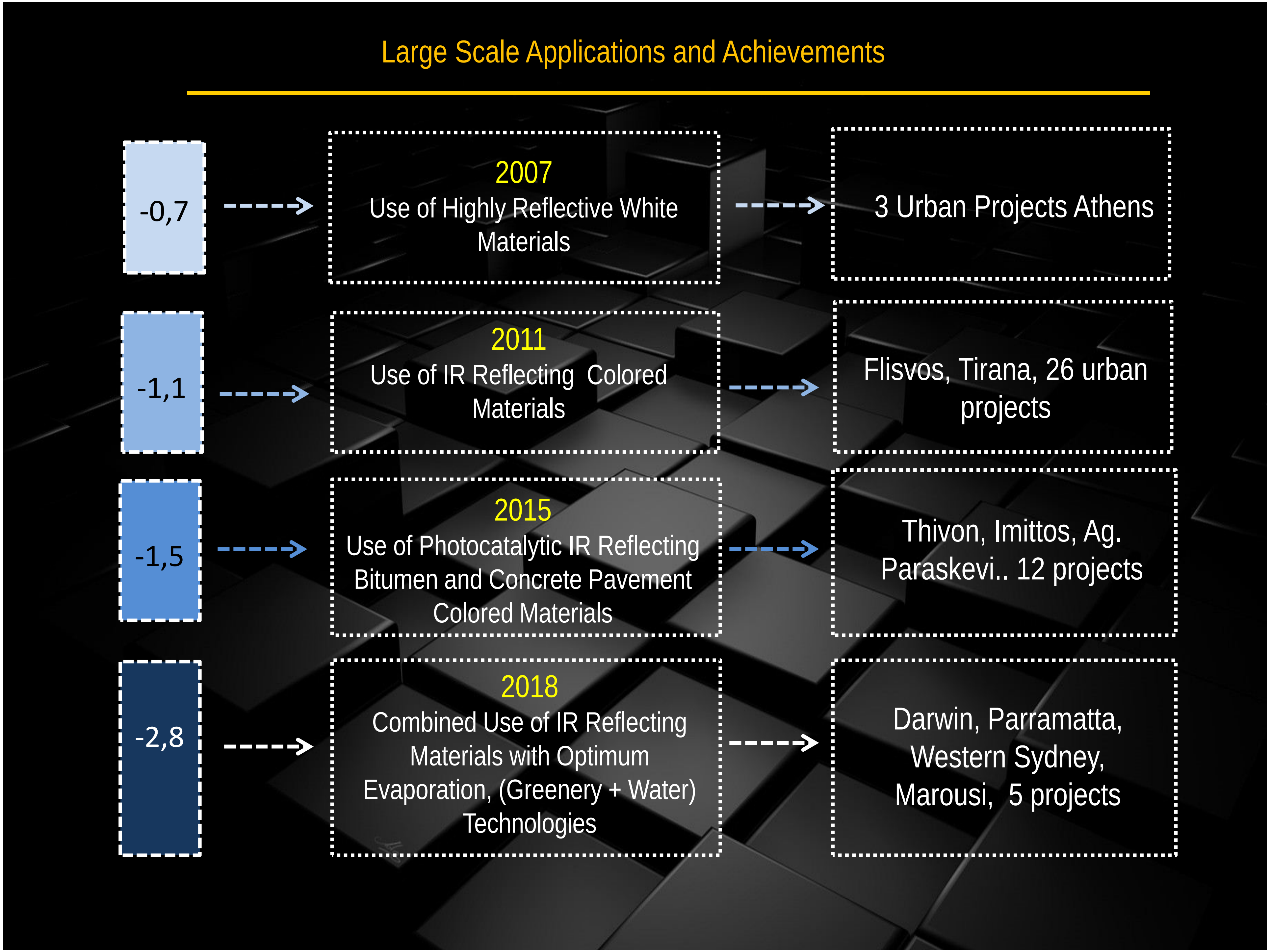
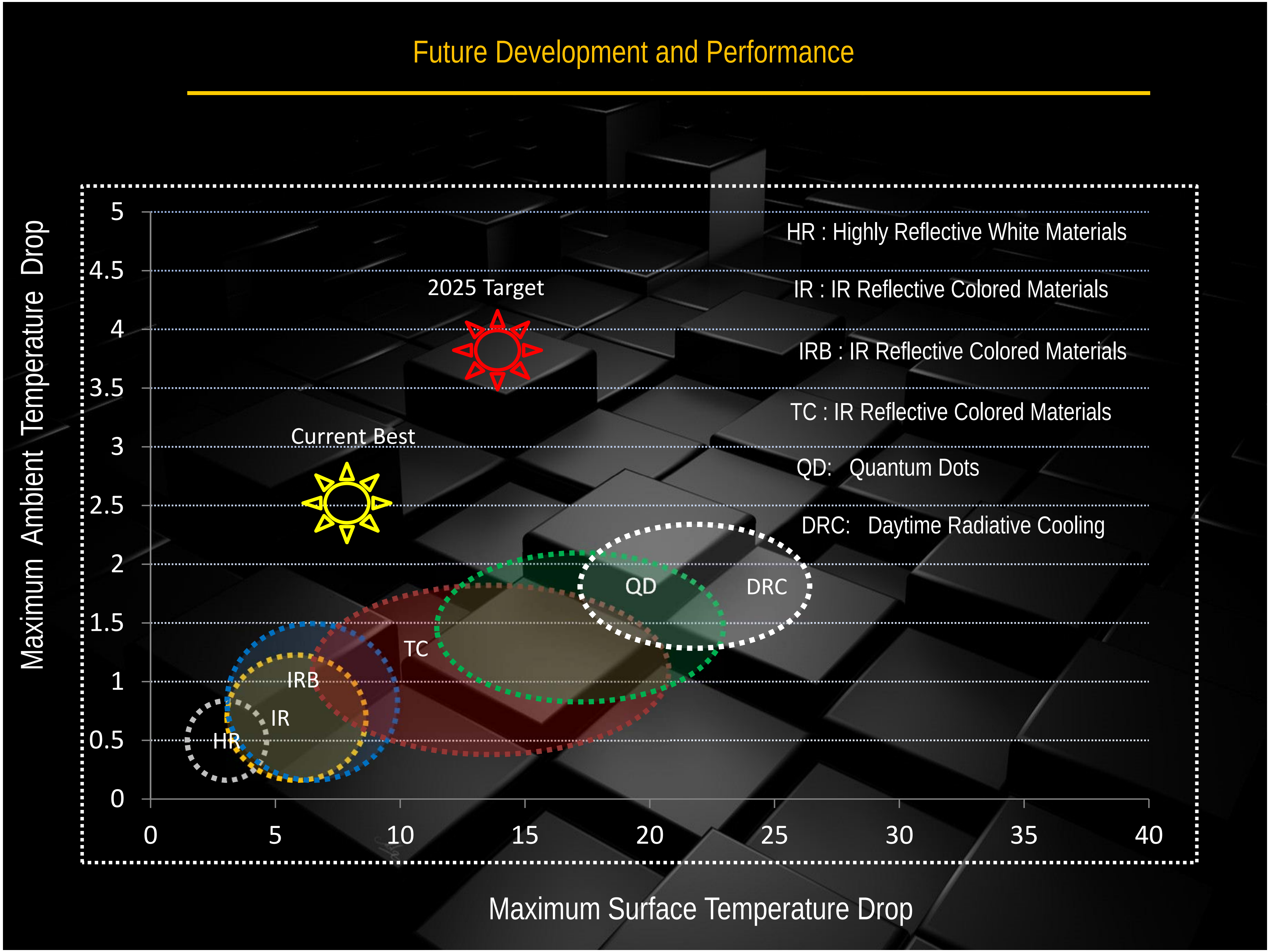

Large Scale Applications and Achievements
-0,7
2007
Use of Highly Reflective White Materials
3 Urban Projects Athens
-1,1
2011
Use of IR Reflecting Colored Materials
Flisvos, Tirana, 26 urban projects
-1,5
2015
Use of Photocatalytic IR Reflecting Bitumen and Concrete Pavement Colored Materials
Thivon, Imittos, Ag. Paraskevi.. 12 projects
-2,8
2018
Combined Use of IR Reflecting Materials with Optimum Evaporation, (Greenery + Water) Technologies
Darwin, Parramatta, Western Sydney, Marousi, 5 projects


Future Development and Performance
Maximum Ambient Temperature Drop
Maximum Surface Temperature Drop
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
2025 Target
Current Best
HR
IR
IRB
TC
QD
DRC
HR : Highly Reflective White Materials
IR : IR Reflective Colored Materials
IRB : IR Reflective Colored Materials
TC : IR Reflective Colored Materials
QD: Quantum Dots
DRC: Daytime Radiative Cooling

Future Challenges and Priorities

1. The Building Sector Faces Major Challenges : Overpopulation, Extreme Urbanisation, Climate Change, Poverty, Slow Technological Development

2. Challenges and Problems have to be translated into Opportunities . Generate Wealth, Employment and Promote Social Equity through the Eradication of Poverty, Mitigation of Climate Change, Decrease of the Energy Consumption, Improvement of the Environmental Quality.

3. Research on Building Physics and Building Science should concentrate on the development of break through and innovative technologies able to provide radical solutions at low cost

4. There is a tremendous future market, up to 2050, exceeding 100 trillion US$ for green and efficient building products, systems and technology.

5. Only those having a vision, translated to concrete research and development plan aiming to develop innovative and appropriate technology will benefit and survive.