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Guide to the implementation of cool surfaces for buildings' envelope to mitigate the Urban Heat Island effects

Leitfaden für die Implementierung kühler Oberflächen für die Gebäudehülle zur Milderung des Urban Heat Island Effektes

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Guide to the implementation of cool surfaces for buildings' envelope to mitigate the Urban Heat Island effects

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European foreword

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Introduction

By 2050, according to UN projections, the world population is expected to reach ten billion people. Today half of the population is living in cities and projections show more than 80 % by 2050. Cities are where 80 % of global GDP is produced, but they are also where 70 % of the energy is consumed and 75 % of waste and Greenhouse Gas (GHG) emitted.

Abating GHG emissions and increasing energy efficiency are at the heart of our European strategy and regulatory framework, with a focus on cities and built areas that offer a high potential for improvement and for meeting the EU Green Deal objectives. Urban Heat Island effect is one important topic both to mitigate climate change and to adapt. Minimizing these Urban Overheating effects contributes to reducing energy consumption by lowering energy demand for cooling and ventilation during hot periods, and thus the related GHG emissions[1], as well as to bringing better comfort to citizens.

This document presents guidelines about why, when, and how to consider mitigation of Urban Heat Island effects with cool roofs and cool materials, as well as reference information about characteristic parameters and how to select appropriate materials.

Cool materials are especially of high importance for new buildings and constructions but also for retrofitting of existing built infrastructures. A cool material is characterised by higher solar reflectance in comparison to conventional roof materials displaying the same colour and high infrared emittance values. Cool roofing products can be applied to all types of roofs including those of residential buildings, apartment blocks, industrial and commercial buildings, hospitals, and offices.

The benefits are direct and numerous, such as reducing the cooling energy consumption and even leading to avoiding the installation of air conditioning, by keeping temperature indexes lower around Renewable Energy Systems (i.e. Photovoltaic) and thus maintaining higher efficiency and longer life of these pieces of equipment, by extending the life of the roofing materials, and of course by keeping the surrounding temperature lower, which impacts the quality of life and health.

This document will also contribute to setting common elements of language (terms and definitions) and raising awareness among decision-makers, urban planners and constructors, both private and public, and among investment institutions and investors, about the benefit of cool materials, as well as guiding them towards the selection of appropriate solutions against Urban Heat Island effect with immediate and long-term multi-benefits.

Whilst the guide focuses on cool materials for roofs it is also relevant to other parts of the building envelope, other construction and built infrastructures, including roads and pavements, by aligning terms and definitions as well as considerations about characteristics of cool materials.

[1] This document is not intended to address consideration about carbon footprint of materials.

1 Scope

The document provides the terminology relating to cool materials and a guide to the implementation of cool surfaces for building envelopes to mitigate the urban overheating effects. It concentrates on the application to roofs.

The document will focus on urban areas for local authorities and building/construction owners.

The users of CWA 17890:2022 will be local authorities, urban planners for cities including construction, infrastructures and landscape architects.

In addition, the terminology and characteristics of cool materials will serve as a reference for other applications where the use of cool materials will have a significant contribution to adaptation to climate change as well as quality of life, such as for roads and pavements.

Whilst reflective surfaces can be very beneficial, they are not appropriate or effective in all climates for all buildings or building constructions and some guidance is provided.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 490, *Concrete roofing tiles and fittings for roof covering and wall cladding*

EN 492, *Fibre cement slates and their fittings for roofing*

EN 494, *Fibre-cement profiled sheets and fittings — Product specification and test methods*

EN 501, *Roofing products from metal sheet — Specification for fully supported roofing products of zinc sheet*

EN 502, *Roofing products from metal sheet — Specification for fully supported roofing products of stainless steel*

EN 504, *Roofing products from metal sheet — Specification for fully supported roofing products of copper sheet*

EN 505, *Roofing products from metal sheet —Specification for fully supported roofing products of steel sheet*

EN 506, *Roofing products of metal sheet — Specification for self-supporting products of copper or zinc sheet*

EN 507, *Roofing products from metal sheet — Specification for fully supported roofing products of aluminium sheet*

EN 508, *Roofing and cladding products of metal sheet — Specification for self-supporting products of steel, aluminium or stainless steel sheet*

EN 534, *Corrugated bitumen sheets — Product specification and test methods*

EN 544, *Bitumen shingles with mineral and/or synthetic reinforcements*

EN 1013, *Light transmitting single skin profiled plastic sheets for internal and external roofs, walls and ceilings — Requirements and test methods*

EN 14509, *Self-supporting double skin metal faced insulating panels — Factory made products — Specifications*

EN 12326-1, *Slate and stone for discontinuous roofing and external cladding*

EN 1304, *Clay roofing tiles and fittings*

EN 13956, *Flexible sheet for waterproofing — Plastic and rubber sheets for roof waterproofing — Definitions and characteristics*

EN 13707, *Flexible sheets for waterproofing — Reinforced bitumen sheets for roof waterproofing — Definitions and characteristics*

EN 15976:2019, *Flexible sheets for waterproofing — Determination of emissivity*

EN 17190, *Flexible sheets for waterproofing — Solar Reflectance Index*

ISO 9346, *Hygrothermal performance of buildings and building materials — Physical quantities for mass transfer — Vocabulary*

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

ASTM E903, *Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres*

ASTM D7897-18, *Standard Practice for Laboratory Soiling and Weathering of Roofing Materials to Simulate Effects of Natural Exposure on Solar Reflectance and Thermal Emittance*

ASTM E1980-11, *Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces*

ISO 14082, *Radiative Forcing Management— Guidance for the quantification and reporting of radiative forcing-based climate footprints and mitigation efforts*

ISO 6707-3:2017, *Buildings and civil engineering works — Vocabulary — Part 3: Sustainability terms*

ISO 16474-3:2021, *Paints and varnishes — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

ISO 16378:2013, *Space systems — Measurements of thermo-optical properties of thermal control materials*

ISO 22969:2019, *Peintures et vernis — Détermination du facteur de réflexion solaire*

ISO 9488:1999, *Solar energy — Vocabulary*

ISO 9229, *Thermal insulation — Vocabulary*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
cool property
property of a material or product of reflecting solar heat by high solar reflectivity (SR) and by high infrared emittance (IE) and thus limiting temperature increase

3.2
cool materials
cool materials are exposed products with specific properties concerning solar and infrared reflectivity and emittance

Note 1 to entry: Only passive cool materials are considered in this document.

3.3
cool roofs
roofing assemblies where the exterior surface has high solar reflectance and high thermal emittance

3.4
heat island effect
tendency of an urban area to be warmer than its non-urban surroundings

Note 1 to entry: For further details see ISO 6707-3:2017.

3.5
infrared emittance
emittance in the infrared range at least from 4 µm to 40 µm (with the full thermal range comprised between 4 and 80 µm)

Note 1 to entry: For further details see ISO 16378:2013.

3.6
solar radiation
wavelength range, typical values, and power should be specified (to explain that between 2 500 nm and 2 800 nm there's not much solar power so the measurements with UV-Vis-NIR spectrophotometers are OK

3.7
infrared (or thermal) radiation
wavelength range and power should be specified

3.8
solar reflectance (SR), also known as albedo
ratio of the reflected global radiant flux to the global solar radiation flux incident on surface in the solar wavelength range (250 – 2 800 nm)

Note 1 to entry: For further details see ISO 22969:2019.

3.9
solar reflectivity
ratio of the reflected solar irradiation from the surface to the solar irradiation incident on that surface

Note 1 to entry: For further details see: EN 17190.

The terms solar reflectivity and solar reflectance have similar definitions and are commonly used by the construction sector. For ease of reading, the term solar reflectivity will be preferred in this document.

3.10
thermal emittance
the thermal emittance of a material (usually written ε) is the ratio (proportion) of the heat energy radiated by a surface relative to the heat energy radiated by a blackbody at the same temperature; it is a measure of a material's ability to radiate heat

Note 1 to entry: Further details see EN 15976:2019.

3.11
bituminous roofing sheet
factory made bitumen sheet including any reinforcements, carriers, facings, surface texture and/or backing

Note 1 to entry: The sheet is part of the roof waterproofing system, which ensures the watertightness. Within the roofing industry it is also called a membrane. An exposed sheet is the roof covering which can be a single sheet (single ply system) or a build-up of several sheets. These sheets can be mechanically fixed or adhered e.g. torched. The sheet is built up with inner layers (e.g. reinforcements ...). Both sides of the sheets typically consist of waterproofing modified bitumen and with additional backing/adhesive or lacquers/surface finish etc. Further details see EN 13707.

3.12
synthetic roofing sheet
factory made plastic and rubber waterproofing sheet, which can be rolled up or folded for easy transport to the site

Note 1 to entry: The sheet is part of the roof waterproofing system, which ensures the watertightness. Within the roofing industry it is also called a membrane. An exposed sheet is the roof covering. This is typically a single sheet (single ply system). These sheets can be mechanically fixed or adhered e.g. glued, self-adhesive etc. The sheet can be built-up with or without inner layers (e.g. reinforcements, carriers…). Both sides of the sheets consist of waterproofing polymer/elastomer and with additional backing/adhesive or lacquers/surface finish etc.

Note 2 to entry: Further details see EN 13956.

3.13
liquid-applied roof waterproofing kits (LARWK)
the Liquid Applied Roof Waterproofing Kits (LARWK) consist of a material or a combination of materials, where at least the main component is liquid form, applied on roofs, terraces or balconies.

In addition to providing a waterproofing layer kit with cool properties act as a reflective layer

Note 1 to entry: Within the roofing industry these systems are also referred to as LAM. For further details see harmonized EAD 030350-00-0402.

3.14
roof coatings
liquid coatings applied on roofs

Note 1 to entry: These coatings do not provide a waterproofing function. For further details see harmonized EAD 030350-00-0402.

3.15
tiles and slates
tiles and slates are usually rectangular, flat or profiled elements, which are discontinuously laid as part of a system to form a weather-tight, air permeable covering on pitched roofs and walls. They are made from durable, hardwearing material such as ceramic (fired clay), concrete, stone, slate, fibre cement,

durable timber, metal, or even glass and are available in a variety of colours and finishes. They may be coated or uncoated.

Note 1 to entry: For further details see EN 1304, EN 490, EN 12326-1 and EN 492.

3.16
shingles
shingles made of bitumen or wood and are fixed in a discontinuous overlapping manner onto a roof substrate, to ensure weather-tightness. Bitumen shingles are factory made and may be multi-layered, with or without reinforcement and surface layers. Wood shingles are factory cut, commonly from red Cedar wood

Note 1 to entry: For further details see EN 544.

3.17
fully supported metal sheet
fully supported metal sheets are typically of zinc, steel, stainless steel or aluminium. The sheets may be coated and available in a variety of colours and finishes and they form a substantially airtight roof covering. Included are prefabricated or semi-formed products (for example metal tiles) and strip or coil sheeting (for example standing seam construction)

Note 1 to entry: For further details see: EN 501, EN 502, EN 504, EN 505 and EN 507.

3.18
self-supporting profiled sheeting
self-supporting profiled sheets, typically of copper, zinc, aluminium, steel, fibre cement, bitumen or rigid plastic. Available in a range of profiles, including sinusoidal, trapezoidal and pressed tile arrays, giving a substantially airtight roof covering, available in a range of colours and finishes.

Note 1 to entry: For further details see: EN 506, EN 508, EN 494, EN 534 and EN 1013.

3.19
double skin metal faced insulating panels
factory made, self-supporting, double skin metal faced insulating sandwich panels, for discontinuous laying of roofs and walls, giving essentially an airtight finish. They are available in a variety of colours and finishes.

Note 1 to entry: The insulating material forming the core is generally of rigid polyurethane, expanded polystyrene, extruded polystyrene foam, phenolic foam, cellular glass or mineral wool. For further details see: EN 14509.

3.20
radiative forcing
difference between the energy from the sun absorbed by the earth and the energy radiated back into space. When incoming energy exceeds energy outgoing, the earth's atmosphere will warm, and global temperatures rise (from ISO 14082)

4 EU strategic context and benefits to use cool materials

4.1 Green deal

The European Green Deal sets out one of the most ambitious road maps for an entire continent, outlining a series of key initiatives to bring greenhouse gas emissions to net zero by 2050.

The European Green Deal supports and promotes a climate-neutral context, with a sustainable economy by deeply transforming sectors like transport, buildings and construction, manufacturing and energy, as well as through policy and legislative proposals – a key part of the Green Deal -, as a major driver to decarbonize our cities and buildings – ensuring it benefits citizens across the EU while keeping housing affordable.

Cities are, indeed, centres of innovation and growth, and the engines of European economic development. They host around 75 % of the population and use about 80 % of the energy produced in Europe, with an expected increasing trend. But cities are also major contributors to climate change, with significant greenhouse gas emissions. In addition, cities are especially vulnerable to the impacts of climate change: extreme heat waves, flooding, water scarcity and droughts can impact health, infrastructure, local economies, and quality of life of city habitants. Over the past decades, Europe has seen a 60% increase in extreme weather patterns [1].

Climate change mitigation and adaptation is among the top priorities of the Green Deal, and Cities and built areas are at the heart of this priority with a high potential in meeting the EU Green Deal objectives. The European Union Climate Adaptation Strategy [2], adopted on 24 February 2021, sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050.

The capacity to prepare for and respond to climate impacts at the local level is crucial. Urban authorities have a catalyst role in getting together all actors to co-develop policies and strategies for territorial development. Urban authorities should play a leadership role to create policies responding to all these needs.

Indeed, vulnerability to the impact of climate change is often a result of inadequate planning or building design. For example, the covering of soil for housing, roads and car parks (soil sealing) increases the absorption of energy from the sun and leads to higher urban temperatures - the so-called "urban heat island effect". At the same time, natural drainage is decreased, which, particularly during heavy rains, can lead to urban floods.

Through appropriate and resilient urban design, the impacts of climate change can be reduced, for instance using green infrastructures such as forests, parks, wetlands, cool materials for walls, roofs and pavement. Such approaches also lead to significant co-benefits, including improved air quality, energy savings, reduce radiative forcing, support for biodiversity and enhanced quality of life, as well as employment opportunities.

Urban Heat Island effect is thus a major topic, where an appropriate urban design/planning with consideration of cool materials contributes in a significant manner to meeting climate change and energy objectives while enhancing the quality of life of all citizens.

Cities have also the opportunity to reduce climate change. Indeed, increasing the albedo of urban and human settlement areas can in turn decrease atmospheric temperature and could potentially offset some of the anticipated temperature increase caused by global warming.

As such, this may be an effective strategy to complement climate mitigation efforts as a way of further slowing the rate of global temperature increase in response to continued greenhouse gas emissions.

If cities in Europe are starting to develop and implement adaptation strategies or action plans, mainly motivated by experiences of extreme weather disruptions, there is still a lack of consideration of the importance of preparing for climate change, a lack of communication about good practices and experiences, as well as of support and guidance documents. Awareness-raising campaign and communication about the maturity and benefits of cool materials on the Urban Heat Island effect need to be intensified and guidance documents to be developed.

4.2 Benefits and opportunities to use cool materials

4.2.1 Conditions to integrate cool materials (when and for what kind of project)

Based on the improvement or the renovation a surface needs, there are several different cool materials that can be used. Cool materials are known for their wide variety and versatility.

On existing surfaces for instance, for retrofitting applications all types of cool material could be applied, provided that they are compatible with the existing materials, meaning that there shouldn't be any risk of unexpected degradation of their main functionalities over time, and neither of the cool material in contact with (e.g. staining or soiling). Moreover, the existing surfaces should have received proper preparation by cleaning, application of a primer or a physical barrier preserving from any interaction.

On horizontal or with low slope roofs, which need revamping, the application of any liquid-type membrane cool material would be ideal. Also, such a roof can be retrofitted by the installation of single-ply or bitumen membranes. In case there is a pre-existing applied cool material, that has lost some of its radiative properties from weathering, or a simple waterproofing material (approx. 5 to 10 years of initial application), but they maintain their mechanical properties, the roof can be recovered with liquid materials to renew or add cool properties.

On the other hand, pitched roof elements can be coated with liquid membranes or coatings of a corresponding colour to add cool properties to the existing structure or be replaced at the end of their life circle by tiles or shingles with cool properties.

Newly constructed buildings, depending on the design and the requirements, can be protected from solar radiation by the application of any type of cool material, besides the common insulation usually integrated into the design.

4.2.2 Benefits to use cool materials

4.2.2.1 Environmental benefits

4.2.2.1.1 Reduce the energy consumption

European Union targets the protection and preservation of the environment by developing short-term and long-term strategies. Cool materials make a great contribution to achieving these targets.

The application of cool materials on a structure can reduce the roof/surface temperature by up to 27 %. This percentage is translated to lower indoor temperatures on the last floor of the building and consequently less energy demand for maintaining the interior comfort conditions.

4.2.2.1.2 Mitigate the Urban Heat Island effect

Building surfaces tend to absorb a significant proportion of the incident solar radiation due to their low solar reflectance. Many materials have albedo in the range 0,1 to 0,3. This is one of the contributing factors to the Urban Heat Island effect; it is important and has been documented. Indeed, the more is the absorbed quote of thermal energy the higher is the increase of i) the material's surface temperature, ii) the corresponding near-surface air temperature, iii) the thermal energy released in the environment as heat.

Cool materials can be employed in the building envelope as a cost-effective and passive strategy to counteract the Urban Heat Island phenomena thanks to their high thermal emittance and high solar reflectance, particularly, within the visible and IR light spectrum. These two optical characteristics allow the material to reflect the solar radiation by a great percentage, limiting the portion that is absorbed by the building elements and then released into the urban environment as heat.

4.2.2.1.3 Reduce power plant emissions, including carbon dioxide, sulphur dioxide, nitrous oxides, and mercury, by reducing cooling energy use in buildings

While there are lower environmental and indoor temperatures, the needs for air conditioning will be reduced. This reduction, eventually, will lead to lower energy productions from power plants and as a result, the levels of hazardous emitted gases will progressively be reduced (and the greenhouse effect development will be delayed) [3].