European Partnership
on Metrology
Delivering Impact

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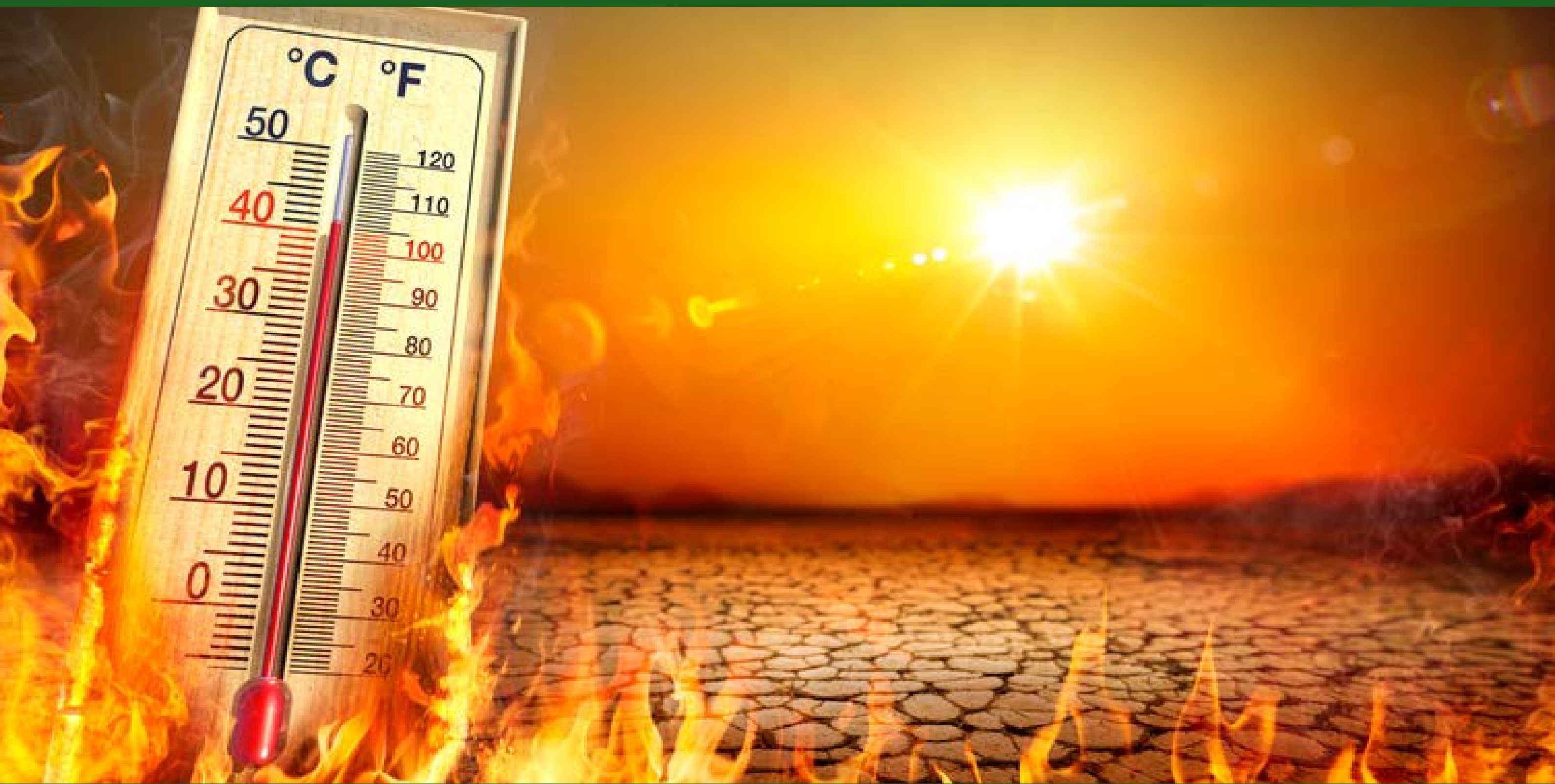

Using outer space as a limitless, energy efficient heat sink

In 2020, cooling systems consumed around 20% of the world's electricity and generated 10% of all carbon dioxide emissions. As global temperatures continue to rise, energy usage is expected to increase over three-fold by 2050, exceeding China and India's current combined energy usage. A new class of materials dissipate heat into outer space without using electricity but require reliable testing protocols to evaluate their performance.

Europe's National Measurement Institutes working together
The European Partnership on Metrology has been developed as part of Horizon Europe, the EU Framework Programme for Research and Innovation. Metrology Partnership funding is drawn from 25 participating EURAMET member states to support collaborative research between Measurement Institutes, academia and industry both within and outside Europe to address key metrology challenges and ensure that measurement science meets future requirements.

Challenge

The vast majority of sunlight reaching the Earth's surface is composed of UV and visible shortwave radiation (≤3 µm). This energy is absorbed by the oceans and landmasses and re-emitted as longwave thermal radiation (4 µm - 100 µm). Although some escapes into space, certain wavelengths are absorbed by atmospheric gases such as carbon dioxide (~ 4.3 and 15 µm) or methane (~3.3 and 7.7 µm). A part of this thermal energy is then returned to the ground, heating up the Earth. As more "greenhouse" gases accumulate in the atmosphere due to anthropogenic activities, like burning fossil fuels, global temperatures are rising.

Passive Daytime Radiative Cooling (PDRC) materials absorb sunlight and re-emit it preferentially at wavelengths not absorbed by greenhouse gases (8 µm – 13 µm) - termed the "atmospheric window". Heat from these materials escapes directly into outer space, generating sub-ambient temperatures even under direct sunlight, without using electricity.

However, PDRC materials also need to be extremely reflective in the shortwave range to prevent solar heating which would negate their cooling effects. This, along with their uniquely tailored optical properties, means commercial instruments struggle to make accurate measurements of their cooling performance. Alongside a lack of validated protocols to substantiate the claims of manufacturers, this has hindered the uptake of these promising materials.

Solution

During the PaRaMetriC project, a systematic characterisation was performed by eleven members of the project's consortium on three commercial PDRC materials. This included intercomparison measurements of reflectivity across the solar range at different angles, emissivity in the longwave infra-red range (including the atmospheric window), and the effects of ageing on performance. Reflectivity measurements utilised spectrophotometers, gonioreflectometers, and integrating spheres, while emissivity measurements were made with emissometers, calorimeters and special reference emissivity setups.

Results confirmed the suitability of the measurement techniques of the PaRaMetriC partners for reliable characterisation of PDRC materials. Good consistency was found in the atmospheric window where all measurements were below 3% uncertainty and traceable to the International Temperature Scale ITS-90.

One material in particular was selected as a candidate reference material during the project, due to its favourable PDRC characteristics, scalability and reproducibility, that of the company SPACECOOL INC.

Impact

The company SPACECOOL INC., a Cool Coalition member within the UN environment programme, was founded in 2021 to commercialise SPACECOOL, one of the world's most widely deployed PDRC materials. With reflectivity and emissivity up to 95% it is thin enough to be cut by scissors (< 0.5 mm), water and fireproof, and easily scalable – from parasols to building-scale installations. Its performance has been demonstrated in a wide range of empirical studies encompassing construction sites, storage facilities, and even to preserving ice on fishing boats. In 2024 a container house equipped with SPACECOOL showed an average decrease in energy usage by 29%, equating to a reduction in carbon dioxide production of 21 tonnes over 15 years. Similarly, in 2025 a pavilion made with SPACECOOL demonstrated a 35–40% reduction in air-conditioning compared to ones composed of other materials, with up to a 9 °C drop in temperature.

Thanks to the project, the company now have rigorous, metrological data to back up the specifications for their PDRC material, information they can pass onto their customers.

The measurement procedures developed in PaRaMetriC will allow a better evaluation and comparison of PDRC materials from different manufacturers – and every m^2 of validated material will help reduce the effect of global warming by emitting heat back to where it came from – outer space.

Developing the metrology for complex PDRC materials

The PaRaMetriC project:

- developed a metrological framework to classify and compare PDRC materials, including "Figures of Merit" and practices for measurement comparisons
- produced setups for reproducible in-field performance testing of PDRC materials
- published an open model for site- and date-specific longwave spectrally-resolved downwelling radiation, along with a dataset of spectral properties of the selected benchmark material in the solar and longwave infra-red range
- established implementations and models for calculating potential energy savings related to using PDRC systems for large scale building cooling
- produced two good practice guides, one for on-site assessment of PDRC material cooling performance to improve their comparability, and one for converting between directional and hemispherical emissivity measurements
- analysed commercial PDRC materials and paints, the latter being used in the Cool White project painting schools and factories in Rwanda

This work will help drive innovation in PDRC technology, producing more energy-efficient cooling to meet rising needs, and in the long-term will reduce the human impact on climate change.

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