Oases of cool: Taking the heat out of urban living

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Can new technology and astute planning keep our cities cool in the face of global warming?

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Understanding heat distribution in our cities is key to making them more comfortable for residents *(Image: British Gas)*

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THE world's coldest capital might seem an unlikely spot for a geoengineering experiment designed to cool things down. But even though the average year-round temperature in Mongolia's capital, Ulan Bator, is close to freezing, the city has to endure sizzling summers coupled with deadly air pollution – a combination that has forced the government to try a novel remedy.

In November 2011, engineers began to drill a network of holes across 30 hectares of land north of the city and fill them with water. The idea is that each winter the water will freeze into subterranean popsicles some 2 metres long, and then melt slowly during the summer, feeding local rivers, helping plants grow and cooling the winds that fan the city.

It's an ambitious project, but if it works it is one that could be emulated elsewhere, given that Ulan Bator's problems are far from unique. More than half of the world's population now lives in urban areas that are getting both bigger and hotter. With climate change set to push temperatures ever higher, finding the best way to cool our cities is no longer simply a question of comfort – it is becoming a matter of life and death.

A recent analysis by US campaign group the Natural Resources Defense Council estimates that extreme heatwaves will kill an additional 3300 people annually in the largest US cities by the end of this century. Simply turning up the air conditioning will make matters worse by pumping hot air into the streets. So how do we cool our conurbations? Can ingenious solutions like the Mongolian "ice shield" really help take the heat out of city life?

The impact that urban development has on local climate was first identified in the early 19th century by British amateur meteorologist Luke Howard, who found that London was 2 °C warmer than the surrounding countryside. The effect is mostly down to building materials like brick and slate, which absorb the sun's heat during the day and release it at night. Thanks to ever larger stretches of concrete, and the prevalence of cars and air conditioning, this "urban heat island effect" has become more pronounced in the last 50 years (see "Snug cities"). Recent studies show that densely developed cities can be as much as 12 °C warmer than nearby countryside.

To make matters worse, global warming will produce far more extreme events, such as prolonged heatwaves, and when these wash over city heat islands, temperatures will skyrocket. The NRDC projects that by 2099, the 40 largest US cities will see an average of nearly seven weeks of extreme heat each summer, an eightfold increase over recent figures. Heat stresses our bodies and also aggravates the effects of air pollution, so mortality rates during hot weather rise steeply with temperature. In 2003, for example, a heatwave in Europe led to 35,000 more deaths than usual, mostly in urban areas (see chart). With more hot days and nights to come, we can expect significant increases in hospital admissions and thousands of extra deaths, particularly among the elderly.

Despite this, the science of urban climate control is still in its infancy, and until recently only limited efforts had been made to understand the details of city climate. The ready availability of air conditioning is partly to blame, says Matteos Santamouris, a physicist at the University of Athens in Greece. But we cannot continue to rely on this technology – it not only worsens urban heat islands but also pushes up energy use. Power consumption typically doubles during the Athenian summer as residents turn to air con.

An obvious way to tackle this problem is to ensure that cities absorb less heat in the first place. So Santamouris and his team are developing paving and roofing materials that are designed to reflect energy away rather than absorb it.

Given that pavements and roofs together can account for more than half of a city's surface area, reducing the amount of heat they store should make a significant difference to street temperatures, says Santamouris. As chairman of the Cool Roof Council of Europe he is spreading the word alongside a long-time advocate of the idea, Hashem Akbari at Concordia University in Montreal, Canada. Akbari is advising the Global Cool Cities Alliance, which aims to install heat-reflecting surfaces in the world's 100 largest cities.

Shiny cities

Is this worthwhile? Experiments show that a reflective roof can benefit a building's residents by reducing their need for air conditioning, so cutting energy bills and carbon dioxide emissions. But proving that reflective surfaces have a beneficial impact on a city's microclimate is more challenging. Most evidence comes from large-scale simulations: a 2010 study, for example, found that installing reflecting roofs in all urban areas worldwide could lead to a 0.6 °C reduction in average urban maximum temperatures. One of the few real-world studies involves the spread of greenhouses in south-east Spain, where local temperatures have fallen by about 0.3 °C per decade as heat-reflecting plastic and glass replace scrub.

Santamouris has carried out what is probably the largest urban trial of reflective surfaces, using conventional construction materials with added inorganic mineral particles that reflect energy at infrared wavelengths. In 2010, 4500 square metres of paving slabs modified in this way were laid in Flisvos Park in Athens. Summertime measurements since then show that the slabs stay about 12 °C cooler than regular paving, and Santamouris reckons that this has helped cool the park's interior by almost 2 °C.

But reflective surfaces could introduce problems of their own. Last year, a study reported that keeping roadside walkways cool by making them reflect energy can lead to the heat being bounced into nearby buildings, increasing the need for air conditioning. A separate study, by a team at Stanford University in California, concluded that widespread adoption of such materials could actually push up global temperatures (see "Weather shapers"). Besides, although reflective materials might work well in hot, sunny parts of the world, in places with a continental climate, like Denver or Moscow, they can increase winter heating costs.

Here, swapping paving slabs for parkland might be more effective. Adding green spaces reduces the urban heat island effect through evaporative cooling and by creating shade – which alone can result in a 7 °C drop in temperature. But adding parkland to already overcrowded cities is rarely practical, especially in areas where real estate prices are astronomical. "Green roofs and walls, and street trees may be more feasible in space-limited urban areas and may, in theory, counteract heat-island effects," says Andrew Pullin of the Centre for Evidence-Based Conservation at Bangor University, UK. But researchers still don't know what kind of vegetation is most effective, or how far cooling effects extend around green areas, according to a meta-analysis of urban greening studies by Pullin and colleagues. It's not even clear how much greenery is needed to compensate for the heating effects of a given amount of asphalt or concrete, he says.

The bottom line is that manipulating the urban microclimate won't be easy or cheap, and analytical tools remain relatively crude – we still lack a simple model to estimate the urban heat island effect, for instance. We need a lot more than just white roofs or extra trees, says Santamouris. Measures that exploit local factors like terrain will also be essential.

In some cities, urban renewal projects are already serving as test beds for this idea. These projects will also be proving grounds for technology that tracks temperature or humidity and can respond where necessary to make conditions more comfortable.

One such project is the Taichung Gateway Park, an ambitious scheme in Taiwan to redevelop the dilapidated neighbourhood around Taipei's old airport. The city authorities gave the contract to French landscape architect Catherine Mosbach, who proposed a green lung designed to tempt residents out of their air-conditioned cocoons. The knock-on effect, Mosbach hopes, is that it will help limit temperature and humidity.

Due to start construction this year, the 2.5-kilometre-long park will contain zones engineered to modify the microclimate in different ways. Some will be cooler and less humid – suitable for outdoor sports, say. Others will help clean the air, thanks in part to paving incorporating catalysts which absorb light and use the energy to break down pollutants in the atmosphere. The park is also landscaped to make the most of the prevailing winds that blow in fresh air. In one spot Mosbach plans to increase comfort by reducing the humidity using an "inverse oasis" – an 18-metre-long platform perforated with holes linked to an electric dehumidifier. The team's simulations predict that the perceived temperature may drop by as much as 4 °C around it. Similarly, a "cold lake" area will pump cool air from electric chillers through layers of plastic flooring and seating. The energy used by the park will come from a set of wind turbines, says Mosbach, so its oases should be sustainable. Yet in a city where humidity often hovers at around 90 per cent, it is unlikely these measures will have much impact beyond the park.

A more ambitious approach is being used to improve the microclimate in the historic centre of Tirana, Albania's capital city. Greek architect Nikos Fintikakis, working with Santamouris, has modelled the impact of various heat-mitigation strategies on temperature and wind speed in the area. The results were so encouraging that in 2012 they renovated a region of about 2 square kilometres, introducing extra vegetation, shading and another of Santamouris's creations – thermochromic paving. This contains heat-sensitive materials which change colour with the temperature. The paving is dark in winter, allowing it to absorb heat efficiently, but as temperatures rise it turns yellow then white, so reflecting more heat. The paving works well, says Santamouris, who is commercialising the system. "The team has reported a 3 °C drop in temperature this summer," says Fintikakis, which matches their predictions.

The final part of the design is a set of earth-to-air heat exchangers. These suck in hot air and circulate it through long pipes buried 3 metres underground, where temperatures are several degrees cooler. The chilled air is then blown out into public spaces through ducts at head height. Fintikakis hopes these will be installed shortly.

Master plan

Tirana's renovation won't stop there. The architectural firm Grimshaw has won a competition to create a master plan for the city, which will roll out similar strategies across some 14 square kilometres.

Ultimately any redesign should focus not only on open spaces, but also on the fabric that actually makes a city a city: its buildings. According to Janet Barlow, an urban meteorologist at the University of Reading, UK, the shape, size and distribution of shops, houses and office blocks can be used to influence wind speeds in "street canyons". Barlow's simulations suggest that a street should be 1.5 times wider than the height of its buildings to create a constant airflow that will cool residents and disperse pollution.

This theory is now being put into practice at PlanIT Valley, an eco-town development in northern Portugal which is due for completion in 2015. Its designers, the company Living PlanIT, have developed a simulation that incorporates the area's topography and meteorology. By looking at the way building size and location affect shade, temperature and wind speeds within the model, they have devised a layout that should increase wind speeds at the tops of buildings for power generation using wind turbines, yet maintain a comfortable breeze at street level.

Buildings themselves could be used to manage their immediate environment, says Roel Loonen, an engineer at the Technical University of Eindhoven in the Netherlands. One example is the Mina Zayed waterfront project being built in Abu Dhabi. It consists of a cylindrical building wrapped in a large moving curtain that follows the sun, providing all-day shade for an outdoor park at the centre of the building. Other active facades are being developed, says Loonen, including thermo-responsive polymers that moderate temperature by changing colour – like Santamouris's thermochromic paving – or "sweating", releasing moisture.

Ultimately, though, low-tech solutions are likely to make the biggest impact. PlanIT Valley includes air conditioning that uses nothing more fancy than ice, made using surplus power from its solar panels.

Chimed-Erdene Baatar, who coordinates the Ulan Bator project for the Mongolian government's Clean Air Foundation, needs no convincing. Their ice shield project seems to be working, she says, and the government plans to roll out this natural air conditioning on a larger scale. It could be adopted in any city with a continental climate, says Baatar, offering cool recreational areas in the suburbs, or integrated into city centres. "The energy savings would be enormous."

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