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The killer outside

About half of the world's population lives in urban areas, where the consequences of climate change are being exacerbated by the urban heat island effect. As Sean McGowan reports, the HVAC industry has a critical role to play in lessening its costly impact.

> "Heatwaves . . . kill more people than any other type of natural disaster"

Considered by many to be a modern phenomenon, the urban heat island (UHI) effect has been observed by researchers since at least the 1830s.

Indeed, decades before others would follow, British chemist and amateur meteorologist Luke Howard's analysis of temperature records in 1830s London resulted in him being the first to detect the impact of urbanisation on the local climate.

His analysis was based on temperature records at three different sites outside London, and one within the city. And although the accuracy of these can be questioned, the "urban influence" on the city quickly became apparent.

Almost 200 years on, researchers the world over have narrowed the categories of the urban heat island effect into two distinct aspects: surface heating and urban canopy-level air heating.

"Surface heating, caused by solar radiation being absorbed by unshaded ground surfaces or buildings, is the day-time element of the urban heat island effect," says Judy Bush, a PhD candidate at the University of Melbourne.

"In contrast, air heating – whereby the higher-temperature surfaces and buildings heat the urban air canopy – is particularly related to the increased night-time temperatures in urban areas."

Although temperatures fall after sunset – even during a heatwave – a study in Melbourne found that 1am temperatures were, in fact, 4°C higher in the CBD and built-up areas compared to the surrounding countryside.

Other studies have found peak heat-island magnitudes as large as 7°C.

Bush says night-time heat can affect our ability to cope with heatwaves – the duration and frequency of which have increased in Australia since 1950.

Judy Bush

"And with climate change impacts, they are projected to increase further in the future," she says.

"Heatwaves impact a city's liveability – the health and wellbeing of its residents and workers, as well as biodiversity, economic activity and infrastructure. And they kill more people than any other type of natural disaster."

A POLICY SHIFT

Bush's PhD thesis which is investigating how policies can contribute to retaining and maximising green space in cities, is part of a larger project investigating urban microclimates through the national Cooperative Research Centre for Low Carbon Living (CRC).

Although green spaces fulfil many roles within a city environment, Bush says they are among the most effective ways to mitigate the urban heat island effect.

For instance, research has shown that a 10 per cent increase in vegetation can result in a 1°C temperature reduction.

When such temperature reductions are overlaid against the temperature thresholds at which heatwave deaths occur in Australian cities, it is clear that even the slightest change in temperature can be a matter of life or death for the elderly, very young and those suffering chronic illness.

Graham Carter, M.AIRAH

"Research is continuing into how size, distribution and total quantity of green space impacts the urban heat island effect," Bush says. "For instance, studies are comparing the effects of one large green space versus many smaller green spaces."

In the meantime, policy makers around the country are beginning to seriously confront the challenges presented by the urban heat island effect.

Local governments, for instance, are considering it as part of their larger climate change adaptation and mitigation plans. The City of Melbourne's Urban Forest Strategy aims to increase canopy cover in the city from 22 per cent to 40 per cent by 2020.

Moreland City Council – which covers the inner northern suburbs of Melbourne – is preparing an urban heat island action plan.

Significantly, a number of councils have also undertaken thermal mapping of their municipalities to identify localised areas that hold higher heat, which can then be prioritised for mitigation treatment. This treatment might include the planting of more street trees or the establishment of "pocket parks".

A report prepared by AECOM and Monash University in 2013 reviewed thermal imagery taken across portions of the City of Greater Geelong and Wyndham City Council (neighbouring municipalities west of Melbourne) to better understand risks and appropriate responses.

It revealed the impact of street trees and carparks on temperature, and identified hotspots surrounding areas with populations that are vulnerable to heat, such as schools. The thermal flyover also revealed the impact of public open spaces, soil moisture and shading from buildings and trees.

COOL ROOFS

The report identified limitations and anomalies in thermal imaging for this purpose (such as the emissivity of surfaces where corrugated iron may appear cold). It also highlighted the abilities of light-coloured roofs to reflect heat and contribute to reduced atmospheric heating.

Bush says this is an area yet to be fully realised by policy makers, building owners and the construction industry generally.

"The colour, type and permeability of building and paving materials impact the amount of solar radiation absorbed or reflected," she says.

"Cool roofs, with light-coloured reflecting materials, are very effective. It's been reported that there can be up to a 40°C difference between cool roofs and traditional roofing materials."

Green roofs are also part of the mix being considered by policy makers because they provide the added benefit of additional vegetation in an urban environment.

Bush says green roofs have not only demonstrated a cooling effect for the building on which they are installed, but they also contribute to broader heat island mitigation.

"The two most important measures for building owners is to make their buildings more efficient to reduce the need for air conditioning, and incorporate green space either at ground level or as green roofs, walls and facades," she says.

"Anthropogenic heating from machinery, including air conditioners, adds to the urban heat island effect."

THE HVAC IMPACT

Fact: we have increasing dialogue in our industry around green, cool and energy-generating roofs. However, Lendlease sustainable design manager Graham Carter, M.AIRAH, says our industry suffers major shortfalls in fully understanding how different roof types affect mechanical system performance.

Along with University of Wollongong Sustainable Building Research Centre lecturer Buyung Kosasih, Carter has written a technical paper, "Not so cool roofs" exploring this topic. The duo analyse the impact of the micro-climate created by a heat-absorbing roof on ventilation-air and condensing-air temperatures.

The authors say this effect – a micro-climate – is ignored by the vast majority, if not all, load-calculation and energy-simulation tools our industry uses.

The result is a failure to account for the full impact of conventional roofs leading to, at worst, an under-sizing of air conditioning equipment, or the full benefits of cool and green roofs being felt.

"The roof micro-climate that is created is analogous to the urban heat island effect, albeit at a smaller scale," say the authors.

"For smaller roofs, the UHI effect is small, and current software provides a good approximation of roof thermal performance; however, for larger roofs like those common for industrial facilities, shopping centres and airports, the roof micro-climate is more significant and can lead to an upward bias in roof surface temperature."

Where mechanical equipment is located on or near the roof, a bias in the ventilation loads or condensing temperatures is created.

The authors cite a previous study that isolated the effect a cool roof had on suction-air temperatures for roof-mounted air conditioners. It found that for a typical summer week, the cool roof treatment lowered the roof surface temperature by 15°K and the above-roof air-temperature bias by 2.1°K under peak solar conditions.

However, a number of limitations in past research led Carter and Kosasih to conduct industry-sponsored research to provide a robust local case study.

They carried out parametric, three-dimensional computational fluid dynamics (CFD) analysis of two roof types on a shopping centre roof in Queensland's Hervey Bay. They wanted to study the roof micro-climate as a function of the convected heat from the roof surface, as well as the impact of ambient wind, roof shape and location.

The outcome of this research revealed that industry simulation tools only account for 25 to 50 per cent of the full energy benefit of cool roofs for larger roofs.

Furthermore, they found that where a conventional zincalume roof is present, peak cooling loads and electrical demands are significantly impacted, with an estimated 14Wr/m² increase in cooling load and a 2We/m² increase in electrical demand across the roof area compared to a cool roof product.

The study also found that the location of the plant room on the roof was an important factor.

Centrally located plant was found to nearly double the average bias and add 50 to 60 per cent onto the maximum air-temperature bias.

"Based on our experience, our industry does not allow for the air-temperature bias in energy or ventilation-load calculations – it is only common to select equipment for elevated service temperatures to reflect ultimate peak ambient conditions and nominal short-circuiting or roof micro-climate effects," the authors say.

"The implications of not accounting for the roof micro-climate above larger roofs are significant, and should be addressed within our industry."

Carter and Kosasih recommend the industry's standard load calculation thermal simulation tools need to account for the roof micro-climate effects. The tools currently underestimate loads and understate the value of cool and green roofs, the authors say.

"With 5 to 25 per cent of total annual cooling load not accounted for in first-order techniques, our tools need to evolve to represent conventional and cool roofs more accurately," they say.

Furthermore, they say the implications for peak loads and passive design are substantial.

COMING TOGETHER

In 2012 the City of Melbourne commissioned AECOM to do a report on the economic cost to the community of the urban heat island effect. The report conservatively estimated the cost to be about $300 million in Melbourne alone.

The additional heat within the city is expected to have a range of impacts on transport and infrastructure operations. But it is the impact on health that is of greatest economic cost.

There is mounting evidence pointing to an increasing negative impact on the liveability of major cities and urban areas around the world. Still, much work needs to be done to see the urban heat island effect mitigated, let alone reversed.

"The effects can definitely be reversed," says the University of Melbourne's Bush. "And with increasing heatwaves associated with climate change impacts, it's more and more important to address urban heat issues."

She says through a mutual determination between governments and "urbanites", priority must be given to finding space for urban greenery. She says greater consideration must be given to urban heat mitigation in the design of buildings, as well as new suburbs.

"The HVAC industry has an important contribution to make," Bush says. ▮

Need to know

The technical paper "Not so cool roofs" by Graham Carter, M.AIRAH, and Buyung Kosasih will be published in a coming issue of Ecolibrium.