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Sustainable Cities 2025 Inquiry

Urban Heat Islands

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Cities modify their climates: urban form, thermal sinks and natural coolers interact with both solar and anthropogenic radiation, absorbing and emitting *heat*: the active ingredient in generating the urban heat island phenomenon. High-rise, high thermal-mass building *canyons* magnify the impact of the built environment on urban climate (Arnfield, *et al* 1999; Santamouris, 2001), trapping heat and distorting air movement. The temperature of this urban air dome ranges up to 10^{o}C (www.NASA), and peaks @ 16^{o}C in Athens (Santamouris, 2001).

Micro-greenhouse warming events result, where local weather patterns are affected - precipitation, thunderstorms, hail and violent winds exacerbated, even downwind of urban hotspots (Bornstein and Lin, 1999). These impacts are over and above the urban warming itself, which has energy, comfort and liveability affects besides serious health impositions on urban populations, particularly the more vulnerable - over ten thousand people dying in France alone during the 2003 heatwave. Human behaviour generally is inherently associated with temperature.

An inevitable consequence of using energy is waste heat, which is deposited in the environment, here the built-environment. Multiplied at urban scale this thermodynamic impact is likely to be considerable. Energy consumed for cooling cities is simultaneously a massive source of GHG emissions; here exacerbated by the urban warming phenomenon.

Anthropogenic lifestyle emissions insidiously add to this warming environment, in particular our ubiquitous use of the internal combustion engine - a potent if invisible source of waste heat. And refrigerative air-conditioners – a standard expectation in high rise buildings which are not readily naturally ventilated - do not neutralise heat but simply shift it from the interiors of buildings to the urban air mass from where, ultimately, it will impinge on the building yet again.

Inadvertently too the impact of urban air pollution/photochemical smog is magnified: evaporative emissions (from vehicles essentially) of volatile organic compounds (VOCs) are three times higher on a warm summers day than an average winter day (see www.LBL).

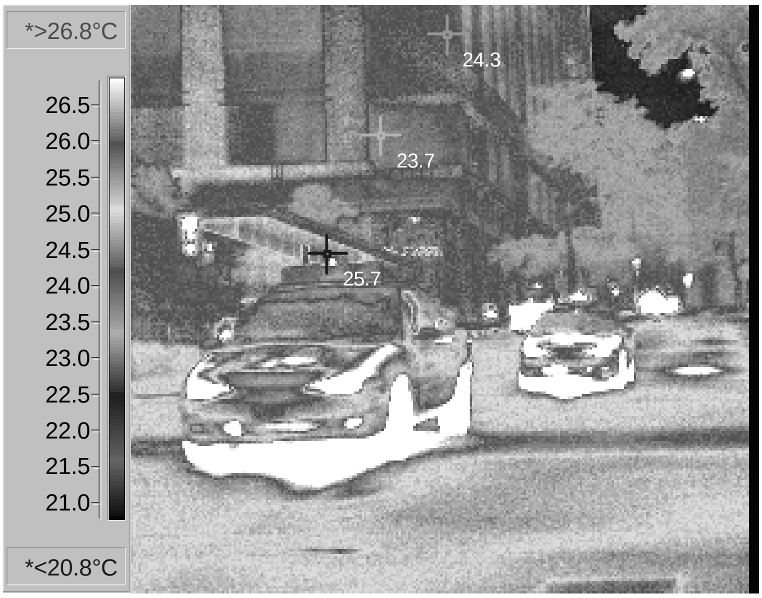
Urban heat is a multi-faceted form of pollution, ultimately.

'Wintry' nations and cold city people might be forgiven for thinking that some warming might not be a bad idea, forgetting that the affect is much more complex, especially an exaggeration of local weather extremes, whatever they are - compounded by the nature of twentieth century cities.

Heat is inescapably embodied in the built environment, at whatever scale. In the thermal images below several such patterns are evident - even an 'urban village' setting, even at Sydney Harbour's edge, is not immune. The evaporative-cooling capacity of trees is also evident (here only relatively cooler, trapped in the heat sink); and the parked cars have now cooled (ie have already emitted their heat), but the road will remain a major source of heat until long past midnight.

‘urban village’ heat emissions @22[h]

Internal combustion engines and exhaust-systems radiate heat above 80^{o}C, and tyres emit at about 40^{o}C – both are off the scale in the image below, but have been measured independently using a hand-held radiant-temperature thermometer. This heat is emitted to the urban air mass, absorbed by the building mass and roads, and re-radiated when temperature gradients permit. Again, trees are valiantly attempting to cool the environment (see also: Givoni, 1991).



Sydney CBD @ midnight; hot buildings and roads radiate heat to the night air; cars are very hot

Without presuming to know the solution, and notwithstanding that the interaction between architectural, urban and natural elements is extremely complex (Givoni, 1998), not to mention the human factors, several 'sustainable design' parameters do seem obvious in this regard. A greener city, first and foremost, would surely act to moderate this heat island effect. Landscape can be integrated into and onto building facades and roofs, and building surfaces can be shaded, while mini-parks, tree-lined streets (also shading road surfaces) and running water - even stormwater absorbed in porous paving (Kinouchi and Kanda, 1998) induce natural evaporative cooling (complicated in humid climates). Minimising the canyon configuration (street width to building height geometry) minimises wind-tunnelling, and also heat trapped and stored in canyons - which otherwise reduces long-wave heat loss (cooling ie) (Oke 1982). Maximising 'skyview (via building setback, height containment and variation, façade slope…and interspersed urban squares) exposes the city to the cool night-sky sink. Scaling back hot transport systems and/or placing them underground (see also Golany, 1996) could simultaneously prioritise pedestrian precincts, with many positive consequences for both sustainability and liveability.

Other urban design parameters also seem to be logically implicated: the compactness of a city (urban mass diminishes heat-exchange capacity or cooling: Oke, 1982), while the contiguity of the streetscape minimises surface exposure to the urban atmosphere. 'Organic' or cellular grids with asymmetrical street structures and multiple urban squares/nodes should replicate natural 'aerodynamic roughness' and natural climatic conditions (thus moderate climate extremes)…while orthogonal (90^o) linear canyon grids 'seriously impact airflow, turbulence and diffusion and hence affect the climate and air quality of urban areas' (Oke and Grimmond 1998).

The benefits of maximising low-emission surface treatments (see Akbari, *et al* 1990: energy-use for cooling buildings *is* reduced) seem less obvious at urban scale given the source of the heat is left unaltered, and bouncing heat back to the urban air mass is the primary generator of urban climate modification, in the first instance. Possibly, systems allowing buildings to absorb urban generated heat and channel it to thermal sinks where it could be recycled and put to use, warming water at the very least - while simultaneously drawing heat away from the ambient air mass – is only a conceptual and technological step away?

Essentially, anything that *minimises* the re-emission of heat and the spatial-disruption of air-mass flow at urban scale can be considered ecologically benign with regard to UHI.

Such design notions are the antithesis of planning visions espoused by the 'new internationalists' in the early 20th Century (Le Corbusier, 1929) and still ubiquitously prevalent today in the urban design policies of both developed and developing countries: high-rise, high-density, car-oriented canyon-cities. Prior to that time urban theorists over the centuries espoused a more climate-neutral system for city planning, from Vitruvius (directing streets away from prevailing winds) via Alberti (narrow winding streets minimising climatic extremes) to Palladio (narrow streets and high houses providing mutual shade in hot climate cities) [see: Mumford 1991 and Morris 1994]. This 'perennial urban design paradigm' is still functional today in 'old city' configurations - despite varying population densities and widely different cultural and climatic settings. Cultural heritage is still intact here too, and together with naturally integrated mixed-land-uses help make these cities particularly liveable. With technologically advanced cool, renewable energy systems invisibly integrated into buildings (and generated throughout cities), a greening city regime, and pedestrian prioritisation, the best of the past and future could coincide (Samuels, 1998; 2002).

For a multitude of reasons, not the least of which is the prevailing uni-dimensional focus on ‘energy’, UHI should be seriously researched and given full consideration in urban design policy. There are still as many questions as answers, certainly. Urban climatologists (the majority of those cited here) tend to have mathematical understandings of these complex relationships, and a preference for simulation models of urban thermal settings. My approach is from the urban design and humanist (sustainability is social and cultural too) points of view – less ‘scientific’ but more holistic and ultimately more realistic, since to my knowledge the applicability of such mathematical models in city design is absolutely minimal: this is *not* how architects, planners and landscape architects think. For these reasons I choose to simplify the complex of interactions via thermal imagery (an expensive alternative: the cameras are sophisticated computers and do not come cheaply); and would recommend a research program comparing infrared imagery of a multitude of urban configurations, in old and new cities alike, and in as many climates as possible, in an attempt to empirically extract thermal principles which might be applied in designing sustainable (ie cooler) Australian cities.

Given that the weather occurs in the troposphere (lower 11kms of the atmosphere) and massive urbanisation is the principal settlement experience of contemporary society, it does not seem farfetched to imagine worldwide urban heat emissions and urban generated greenhouse-gases synchronously impacting on global climate too.

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◊ Thermal Photographs: Author