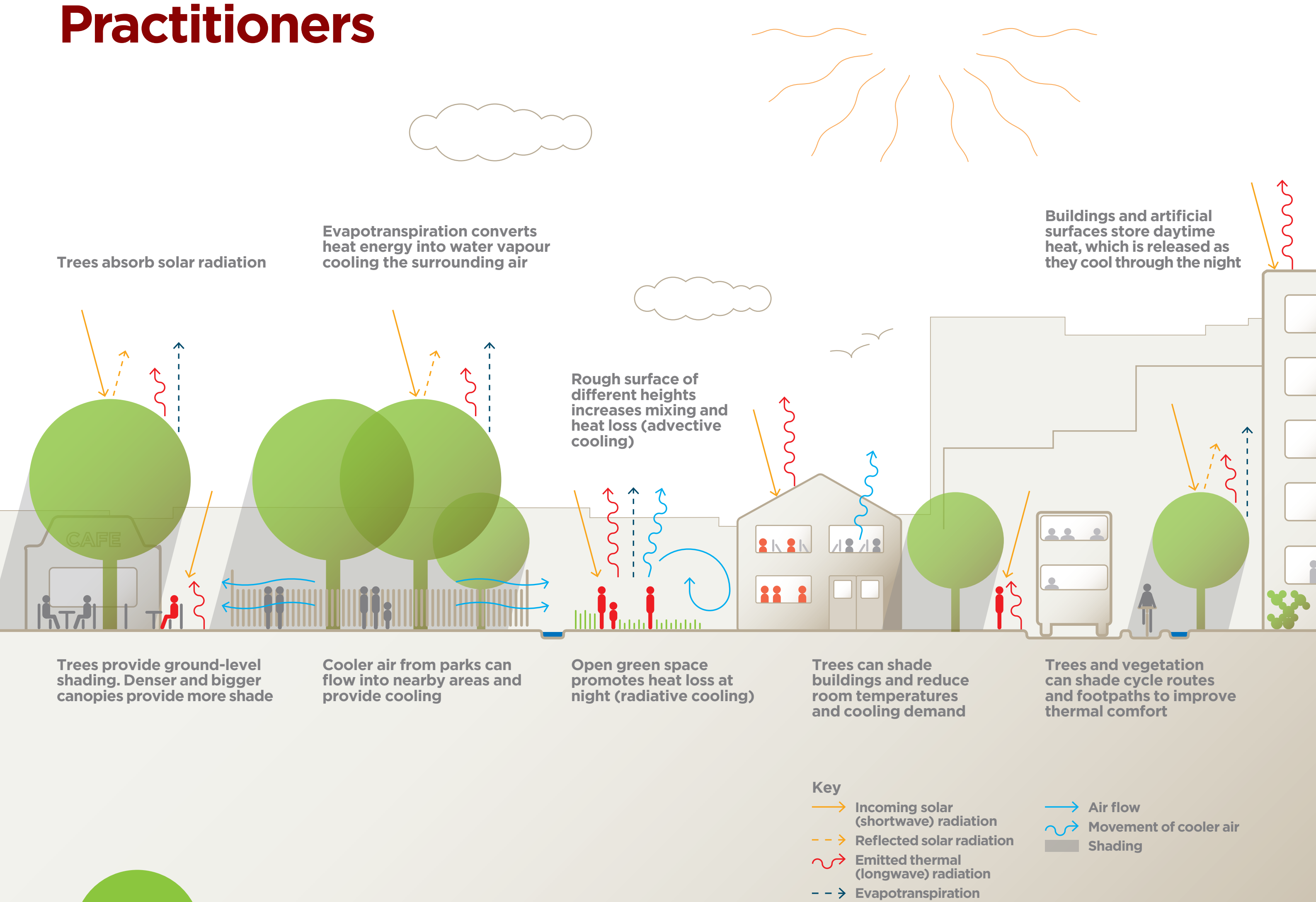
First Steps in Urban Heat

For Built Environment Practitioners



Trees & Design Action Group

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References
1 Terms highlighted in *green italics* are defined in the **Glossary**.

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Urban areas are often 1-2°C warmer than non-urban areas as a consequence of their modified land surface

Urban areas typically have more artificial surfaces that have a lower *albedo*[1], store more heat and cool down slowly. Moreover, *urban form* changes air flow, and can trap heat, or limit or slow the loss of heat to the atmosphere. Lastly, waste heat from buildings, industry and transport adds warmth. The difference in air temperature between urban areas and their non-urban surrounds is called the *Urban Heat Island (UHI)*. The intensity of the UHI generally increases towards the urban centre, which is typically denser and has less vegetation. UHI magnitude is greatest on still, summer nights, when urban areas cool more slowly than their non-urban areas.

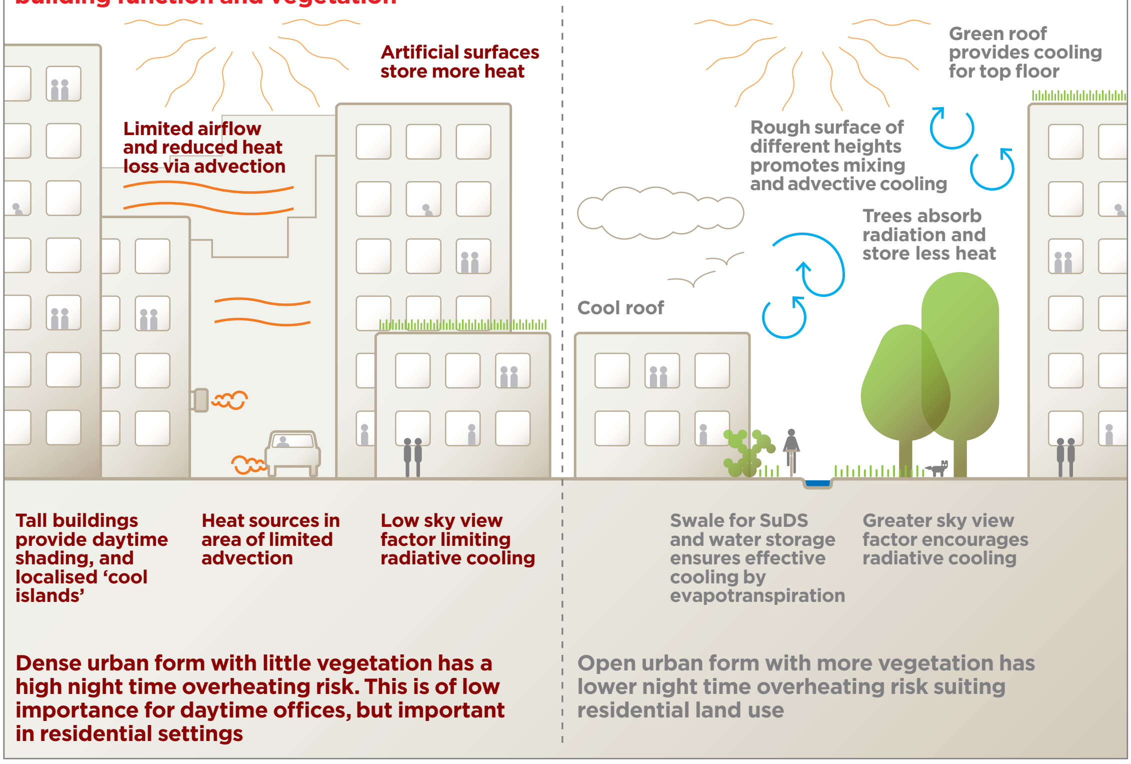
We must consider urban heat in the planning and design of urban areas (Table 1). Climate change is increasing both the frequency of hot summers, and the temperature of hot summer days[2]. High outdoor temperatures impact *thermal comfort*, productivity, and infrastructure[3]. Heat-related mortality will increase in the future[4]. However, the UHI is complex, varying with meteorology, season, time of day, and between neighbourhoods and streets (Table 2). Overheating risk is seasonal, and linked to building function and surrounding urban form (open versus dense; green infrastructure (GI) provision; Fig 1). Buildings provide shade improving thermal comfort. Urban form can give rise to *urban cool islands*, where high-rise building and/or modified air flow make parts of the city cooler than their surrounds during the day[5]. The winter UHI (driven by waste heat[6]) can be beneficial, reducing fuel bills[7] and cold-related deaths, which currently exceed heat deaths in the UK[8]. This guide explains urban heat, the role of GI, and how to include heat sensitive planning and design.

Urban heat and overheating risk

As the sun rises it heats the land surface. Densely urbanised areas store more heat, and cool down more slowly at night than open space. This makes them warmer at night than less urbanised areas that have a more open view of sky (Fig. 1). Limited cooling of the land surface causes heat to build over still, hot days in summer when daylight hours are long and the sun's energy

Table 1 **The need for heat sensitive design**
Health: 20% of homes in England overheat[3] and overheating-risk will increase in the future, particularly for vulnerable and elderly populations[4]. Overheating risk can occur alongside poor indoor air quality[9].
Climate Mitigation: the government has pledged Net Zero emissions by 2050, and many organisations have declared climate emergencies. Heat sensitive design reduces summer cooling demand and winter fuel bills[7].
Climate Adaptation: hotter temperatures and heatwaves are becoming more frequent. Heat sensitive design is needed at all scales (urban to building) to increase infrastructure and built environment resilience and improve thermal comfort[10].
Air pollution: features that promote cooling like open space and good ventilation also benefit air quality[11].
Environmental Justice: vulnerable communities are more likely to live in dwellings prone to overheating, and have less access to indoor cooling or cooling urban green space, exacerbating existing health inequalities and inequities[12].

Fig. 1 **Overheating risk for a given landscape and climate depends on urban form, building function and vegetation**



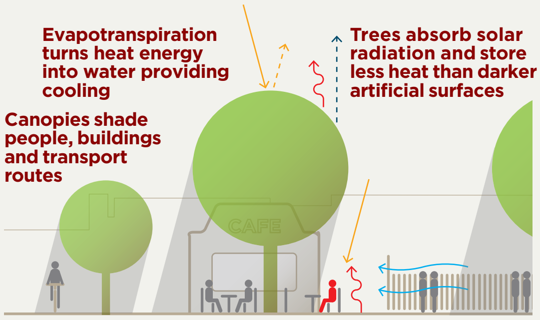
is most intense. Table 2 details the factors that influence urban heat. Generally, the hottest urban areas are those which are most densely urbanised and have least green and open space. In terms of buildings, single aspect flats, particularly the top floor, and/or dwellings that require natural ventilation, but where windows cannot be opened due to noise, pollution or safety, are at the greatest risk of overheating[10]. Vulnerable groups include older people, children, or those with disabilities or with pre-existing health conditions[10] and care should be taken to ensure vulnerable people are not housed in dwellings at risk of overheating.

The Local Climate Zones framework[13] provides a means to categorise urban form and infer likely surface cooling within the context of the landscape; Table 2. Dense landuse will retain more daytime heat, and cool more slowly at night because there is less opportunity for, *radiative* and *advective cooling* than in open landuse (Fig. 1) leading to comparatively higher night time temperatures. Developments in areas of dense landuse therefore have greater potential risk of overheating. The associated health risk will depend on building function, eg the night time overheating risk for commercial landuse is less problematic than residential. By combining guidance on residential overheating risk[14, 15] with an urban form/function led approach as part of strategic planning and development approval processes, it is possible to avoid worst case scenarios, such as vulnerable groups in vulnerable housing.

Table 2 **Factors affecting urban heat**

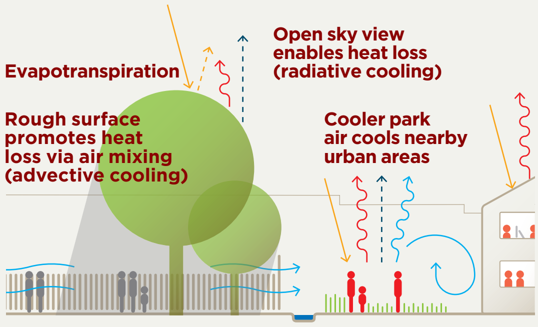
Factor	Effect	Mitigation
Meteorology	UHI is greatest in dry, still (anticyclonic) conditions with limited wind to mix and disperse heat.	Use urban-scale design to promote air flow and mixing (and prevent heat build-up).
Time	Typically the UHI is greater at night as densely urbanised areas retain heat and cool more slowly.	Consider timing of landuse; night time overheating is less problematic in empty offices.
Climate change 16	Hot days increasing in frequency and temperature. Trend towards drier summers (especially SE England) and increasing drought risk. Drier weather reduces cooling by evapotranspiration.	Use climate projections to understand future trends and climate risks. Plan and design-in cooling (eg blue-green infrastructure) as urban areas have long lifespans and will exist in hotter temperature extremes.
Landscape 13,15,17	Topography influences wind strength, direction, and turbulence, influencing dispersion of heat. Urban areas in valleys or at the base of slopes may have reduced air circulation and heat dispersion. Coastal areas have onshore/offshore winds.	Use landscape level-design to promote air flow and mixing. Support water storage and blue-green infrastructure to maximise landscape cooling potential. Dry natural land surfaces behave similarly to artificial land surfaces without water and/or vegetation.
Urban form 13,15,17	The 3D form of streets and neighbourhood, such as street width, building height and orientation, determines air flow, sky view factor and how easily an area can lose heat by advective mixing or radiative cooling.	Opening up urban areas to increase sky view factor (radiative cooling) and promote air flow, ventilation and mixing (advective cooling) can increase heat loss.
Building function 14,17,18	Building function and occupancy pattern (eg residential versus commercial) determine overheating risk (Fig, 1). Care homes, schools and hospitals have vulnerable populations at risk of overheating.	Undertake heat-risk mapping across urban areas and consider placing vulnerable populations/occupancy patterns in areas of lower overheating risk (eg less dense or with more GI).
Materials and ventilation 17,18,19,20	Materials and colour determines albedo and heat storage. Glazing can reflect heat away, sometimes onto other surfaces. When transparent it increases internal temperatures and heat storage. Inadequate ventilation can prevent heat dispersion and cooling.	Consider material use in UHI, particularly specific materials designed for cooling eg cool pavements, cool roofs, green roofs and facades. Ensure sufficient natural ventilation to prevent reliance on air-conditioning for cooling.
Emissions 21	Waste heat from transport, industrial/residential heating/cooling and people adds warmth to areas.	Use passive cooling techniques wherever possible to reduce heat emissions from air conditioning.
Blue and Green Infrastructure 19,20,22,23	Blue green infrastructure provides cooling via: high albedo, shade, evapotranspiration, sky view, at a range of scales from local (green roof) to neighbourhood (park) and city wide (strategic GI design). Water is essential for cooling via evapotranspiration, and can lower urban temperatures.	

Fig. 2 **Cooling provided by trees***



*Trees have sufficient water

Fig. 3 **Cooling provided by vegetation***



*All trees and parkland have sufficient water

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Glossary

Albedo.
How reflective a surface is. White has a high albedo.

Advective cooling.
Loss of heat from an area by mixing and dispersion.

Evapotranspiration.
Combines evaporation and transpiration. Evaporation is the process by which water from soil and plant surfaces changes from a liquid to a vapour. Transpiration is the process by which trees absorb water through their roots and transfer it up to the leaves where it evaporates into the environment through leaf pores.

Radiative cooling.
Loss of long-wave radiation (heat) from surfaces which are open to the sky.

Thermal Comfort.
How comfortable an individual feels with the temperature conditions, ie not too hot or too cold.

Urban form.
A city's physical characteristics. It refers to the size, shape, and configuration of an urban area or its parts.

Urban Cool Island.
Localised cool spot in an urban area, occurring more commonly during daytime and near parks.

Urban Heat Island.
The difference in air temperature between urban areas and non-urban areas in °C (in UK).

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Importance of Green Infrastructure (GI)

GI, including public streets, and private trees, vegetation, open green space (eg parklands, private gardens), and green roofs and walls provide cooling in several ways[22]:
Shade: trees absorb radiation in place of individuals, buildings or infrastructure. Trees provide ground-level shading improving outdoor thermal comfort, plus shade and cooling for low-rise buildings reducing cooling energy demand[24]. The bigger and denser the canopy, the more shade. (Fig. 2).
Open view of sky (sky view factor): parks, gardens and other open spaces with more sky visible cool the surface by facilitating the loss of long-wave radiation at night (*radiative cooling*). Open spaces with no shading have low thermal comfort on hot days.
Rough surfaces: encourage the formation of eddies, increasing turbulence and mixing of air (advective cooling; (Fig. 3).
Evapotranspiration: vegetation uses absorbed solar radiation to evaporate water from within their leaves or stems. This cools the plant down and reduces the heat available to warm the surrounding air. (Fig. 2).
Lower heat storage: vegetation has a relatively low heat capacity, and so stores less heat than other surfaces, and so has less heat to release. This effect is observed at night, when open vegetated areas cool more quickly than densely urbanised areas (Fig. 2 and 3). Conversely, forested areas or dense canopies can prevent radiative cooling and trap heat. However their shading and evapotranspiration during the day are of greater importance for reducing urban heat.
Cooling winds: cooler air from parks or vegetated surfaces can flow into the surrounding areas. Generally the greater the green space, the more spatially extensive the cooling it can provide[22], but this is influenced by other factors (Table 2), particularly meteorology and urban form.

Water (blue infrastructure) is crucial

Trees and vegetation provide most effective shade when they are healthy and in full leaf. The rates of radiative cooling and evapotranspiration are linked to water availability[26]. To maximise the cooling potential of trees and vegetation, blue infrastructure must be integrated with GI to support water storage and availability. Important factors to maximise the cooling potential of trees are given in Table 3.

What can built environment practitioners do?

Consider urban heat from the earliest stages of planning and design, particularly when considering areas for strategic growth or land allocation. This prevents the placement of vulnerable communities in areas of high overheating risk, and allows heat sensitive design (eg GI and blue infrastructure, open form) from the outset. Urban-scale heat-sensitive design can work with existing breezes to improve or create urban-scale ventilation. New developments are an opportunity to mitigate existing UHI effects, and align with other environmental goals for climate mitigation, adaptation, and natural capital restoration.

Key steps

1. **Understand the UHI intensity**
   Where measurements are unavailable, the most intense UHI is likely co-located with high density urbanisation and least open and/or green space. Some large cities (eg London) are considered entirely within an UHI, but its intensity varies considerably. Mapping Local Climate Zones[13] helps categorise urban density and green space. If making measurements, take these under clear, calm conditions at night to assess maximum UHI magnitude.
2. **Heat sensitive strategic planning**
   Consider the development's function in relation to the UHI and Local Climate Zones to prevent lock-in, eg a residential development in a dense urban form that will require air-conditioning without suitable natural ventilation or mitigation via building design and materials[27].
3. **Consider site design and materials**
   This includes the urban form and its sky view factor, GI and cooling materials such as green roofs and cool pavements. These determine heat loss and thermal comfort, both on and beyond the development. Consider mobility; how will people travel to/from the site and what heat will they produce?
4. **Assess building overheating risk**
   Building interior and exterior thermal comfort are determined by surrounding urban form, building design and ventilation, and function[13,14,15].
5. **It is never too late to mitigate**
   Many of the mitigation techniques can (and should[3]) be applied retrospectively.

Table 3 **Factors for planting for cooling**
(adapted from Forestry Commission[22])

Plant Selection[25]	Planting Conditions
- Suitability to site. - High reflectance eg light colour leaf. - High transpiration rates eg species with broad leaves. - Large stature trees with wide, dense canopies and/or high density of leaves to provide shade. - Drought tolerant.	- Adequate water supply. - Ample rooting space. - Un-compacted and fertile soil. - Use vegetated surfaces or permeable/porous pavements. - Appropriate site design eg space to grow, sufficient light, aspect.