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White Paper: The urban emergency

The urban climate and air quality emergency
Cities are critical for solving problems associated with global climate change. They currently cover less than 1% of global land surface area [1] whilst accounting for 70-80% of CO_2 emissions associated with energy consumption [2]. Not only are cities a primary driver of climate change but they are often located in areas where risks are greatest from changes in the intensity and frequency of climate events. They are often located next to the sea, rivers or in valleys.

With almost 80% of people currently living in cities within the developed economies [3], achieving net zero and decarbonisation targets by 2050 (UK target) **will not** negate the need to adapt to the global changing climate. In fact, there is an increased urgency to adapt an increased population exposure to risks impacting our collective health, wellbeing and productivity. If a large tree in one location forms part of a local solution, then there is a long lead-in time to full growth! Long-term planning for the urban environment is therefore essential if we are to become more resilient. Furthermore, the background climate will likely become more hazardous and challenging for many decades beyond achievement of multinational decarbonisation goals, even if successful on this front. Decarbonisation and temperature stabilization is a global necessity [4] but, as always, the most vulnerable will be at greatest risk from our changing climate. Negative impacts will also include more flooding and drought events as well as greater loss of biodiversity [5].

Ambient (outdoor) air pollution is one of the greatest environmental risks to our health leading to, for example, increased levels of heart disease, lung cancer and premature deaths. Almost everyone lives in environments exceeding WHO guidelines [6]. Some children are exposed to pollution levels leading to reduced lung capacity and lifelong breathing disorders [7]. European studies on heatwave episodes have consistently shown a synergistic effect of air pollution and high temperatures along with allergen patterns and associated risks changing in response to climate change [8]. While the uptake of electric vehicles will reduce emissions of some pollutants, it will lead to only marginal future decreases in total PM emissions from road traffic, with most non-exhaust emissions remaining [9]. All routes to improving air quality should form part of a wider urban adaptation strategy. In fact, when examining the long list of benefits on many levels, adaptation should be considered, amongst other things, an economic necessity. Together with the adoption of climate change mitigation strategies, urban adaption is an essential part of the additional resilience we need to build into our cities [10].

The urban environment
An urban environment can be thought of as an ecosystem made up of biotic or living components (all plants, animals, and microorganisms) and abiotic or non-living components such as temperature, light, moisture, and air currents, all of which impact the ecosystem to some degree [11]. The relationships and interconnectivity between these components will ultimately define the resource efficiency, comfort, health, and well-being, as well as the productivity and value of the overall system. In addition, the urban environment can be

considered an ecosystem made up of a hierarchy of complex systems applied at different scales (building, community, city, region and global), all of which can be directly or indirectly impacted by our designs.

Building engineers have opportunities to understand and manipulate these ecosystem components through the design process and drive improved environmental performance whilst exceeding minimum (compliance) targets required for the planning process, guidelines and/or regulations. The additional insights derived from studying the urban environmental *holistically* can lead to multiple environmental benefits, such as cooler air to counter overheating risks associated with the urban heat island and cleaner air to counter pollution effects, whilst also delivering significant economic benefits, such as reduced demand requirements for installed systems through moderating external extremes. 'All-year' benefits derived through designing the urban morphology together with its surface properties could lead to significant benefits over just designing for a high heat scenario.

A surface provides the medium for the heat from the sun (direct, diffuse and reflected radiation) to change the temperature of the air next to it. As air speeds near the surface increase, more surface heat is exchanged with the air through convection. Conversely, at lower air speeds more surface heat is exchanged with the surrounding surfaces and sky through longwave radiation. Local air and surface temperatures will vary in both scenarios even if ambient air and solar conditions are the same. The surface-to-air heat exchange is also affected by the surface properties, thermodynamics with ground connection and sky radiative cooling.

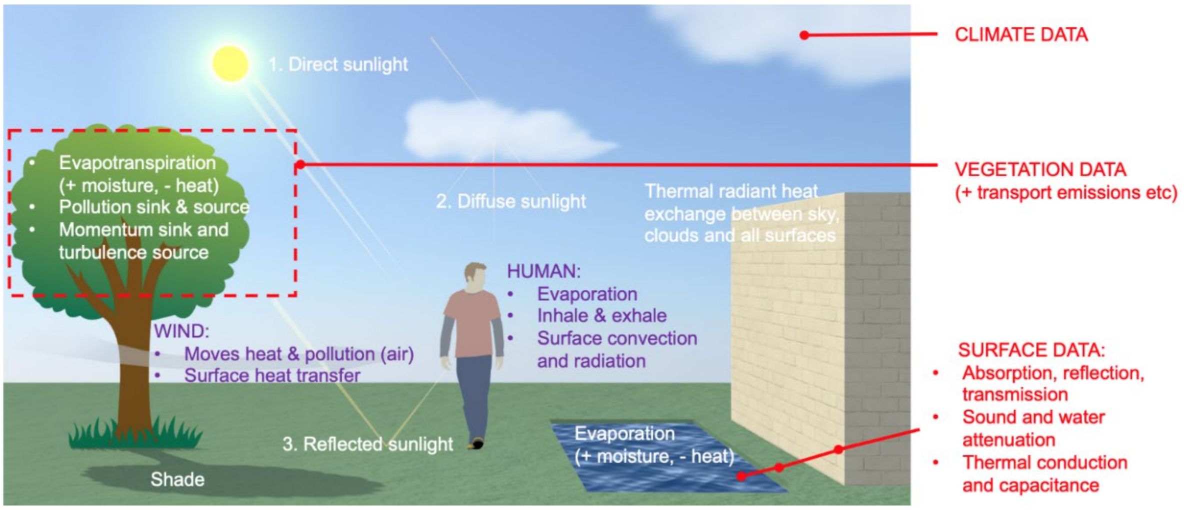

Figure 1. Urban physics - the science and engineering associated with air, heat, light, sound, water and surfaces then its *holistic* application within the urban environment.

It is important to understand wind and urban morphology if the thermal and air quality environments are to be effectively and efficiently improved. There are many factors influencing the urban environment as well as our computational and physical models [Figure 1]. There can, though, be factors that may be outside the standard models that drive our designs. For example, in London the urban heat island impacts, largely driven by our surface materials and urban morphology [Figure 2], may be considered a separate design risk to countering an increasing frequency of Saharan heat coming from continental Europe.

Surface cover – vegetated/built   Fabric – glass, asphalt, concrete   Geometry – street canyons

Figure 2. "Urban form alters the natural exchanges of energy and water between the surface and air." Gerald Mills, University College Dublin.

The following links take you to the related features on:

- Wind
- Thermal environment
- Air quality
- Acoustics

Finding the right balance

The positioning of an urban design for optimum wind, thermal environment, air quality and acoustics, in combination, needs to be made in consideration of surface materiality and urban morphology together with multiple inputs (e.g. pollution sources) and outputs or performance targets that are deemed acceptable. Best practice might be to employ systems theory to capture all of these elements, especially if extended to considerations on health, wellbeing, productivity and asset value. A systems approach is also recommended for the most effective delivery of the 'net zero challenge' at scale and pace [12].

Eventually, systems theory applications for improved urban environmental quality may become more commonplace. The immediate challenge though, in response to the urban climate and air quality emergency, is to bring as many of these elements as possible into *combined* consideration where practical to do so and to do this at scale and pace. It's a matter of developing and applying good practices now *without* the need for significant skills development but *with* the need for much better current working practices. Significant savings in a development *could* potentially accrue as well as a much better understanding and delivery of the many co-benefits.

A natural extension to the surface designs considered above is surface water and drainage systems for improved climate resilience. Additional water storage and attenuation capacity can be generated through, for example, nature-based solutions which can reduce the risk of flash floods within certain limits [13]. Reducing the burden on our combined sewage systems is an additional benefit. A national scale deployment strategy is needed for sustainable drainage systems to future proof our wastewater infrastructure in a changing climate [14]. A key challenge, though, is to move from a mindset of wastewater to 'wasted water' as water is precious to life and improves the performance of our urban vegetation systems which are needed to increase our urban climate and air quality resilience.

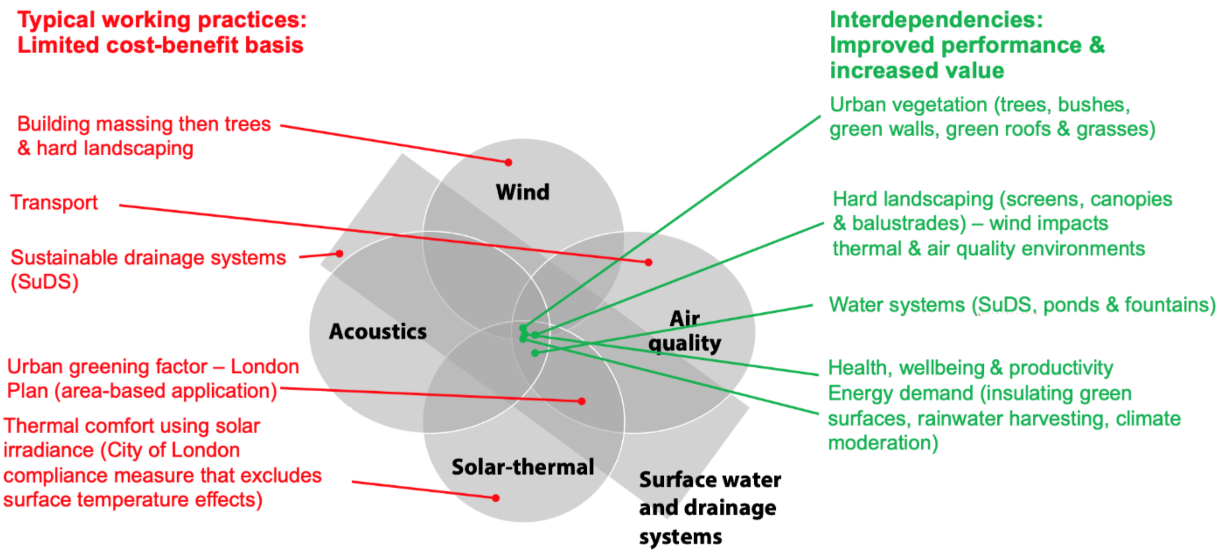

Figure 3. Urban soup concept. Moving to better working practices for improved climate and air quality resilience. [15]

There are many opportunities to improve urban environmental quality through adopting a more *holistic* approach to environmental assessments. One conceptual way to look at this is that our key urban design elements (wind, thermal environment, air quality, acoustics and surface water & drainage systems) could be considered the ingredients of an 'urban soup' [Figure 3]. The 'best recipe' and 'preferred taste' in a particular location is typically undefined and unknown. Best practice guidance to define the recipe and taste has not yet been developed. We know that cost-benefit analyses associated with typical current working practices are significantly limited. The decision-making process for our urban designs could therefore be considered deeply flawed leading to poor design and low levels of resilience.

Unfortunately, our industry's typical design processes are where individual design disciplines tend to work in isolation, often with little communication at the engineering level or cross-over points defined between them (see recommendations in the next section). If cross-disciplinary objectives are developed, targeted and assessed *holistically*, this could result in improved urban environmental quality and a better understanding of the way that constraints, sometimes just perceived, may have on environmental performance. To find the right balance for the design environment and reduce the risk of negative conflicts and consequences, early design discussions should include how urban physics, in its wider context, and other urban design considerations could potentially lead to significant and high-value gains with estimated individual AND combined impacts assessed during the various design development stages.

Finding the right balance requires a much better understanding of the interdependencies, 'weighted' preferences and how they perform in different scenarios.

Current approach and the need for change

Research and innovation in the UK are central to its ambition to "become a scientific superpower", "tackle this country's unresolved challenges" and "level up" [16]. More investment is needed, particularly if we are to maintain competitiveness on a global scale.

As we progress technology in the building industry, we still experience failures and poor performance. Social, economic, and environmental progress with a growing urban population and global environmental change requires new or revised methods and technologies to be established and, in application, improve how urban environments perform. As the outdoor urban environment has a significant impact on the indoor built environment (and vice versa), all co-benefits and targeting for the built environment on energy, overheating air quality etc. [17] should ideally be considered together along with perceived and actual project constraints if we are to optimise and/or 'find the right balance' for our designs. Thus, there is a need for increasing collaboration and integration across all aspects of a very disjointed industry to improve safety, performance and future proofing.

To increase resilience of the urban environment, more R&D is needed to improve methods, technology, and overall sustainability [18]. The definition of urban resilience itself is multidimensional in nature [19] and requires a multidisciplinary approach if many aspects are to be considered on a building project. Typically, only a very limited selection of possibilities will be considered on a project and a small fraction of those implemented. Knowledge gaps remain significant impeding all practitioners' ability to enhance societal resilience and address poor environmental, energy and health issues. Overall, there is much to do to bring all aspects into a collaborative and integrated approach to solve the problems of the future urban environment.

In our urban environment designs we will need to make important progress to tackle the many challenges. And so, the built environment industry needs to change. One recent significant change is the introduction of the Building Safety Act 2022 and its subsequent secondary legislation 2023 [20]. There is also new guidance on biodiversity net gain [21] and new policy on sustainable drainage systems is possibly coming [22].

Designers, manufacturers, specifiers, constructors, maintainers, project managers, various consultants and clients will need to work together much better than in the past. In addition to improving methods, technology, and overall sustainability, more R&D is needed to improve the overall delivery and operational phases of buildings. The largest challenge is the stock of existing buildings. Co-ordination between design, construction, maintenance and considering end-user experience when designing the urban environment requires improved collaboration and significantly reduced barriers. **We have entered a period of emergency. Time is running out.**

CIBSE Resilient Cities Group & UK Urban Environmental Quality (UKUEQ) Partnership
Resilient Cities Group was set up to provide a focus within CIBSE on leadership and knowledge within the area of adaptability, sustainability and resilience of cities whilst bringing together industry experts in a discussion and dissemination forum. In 2022, the UK Urban Environmental Quality (UKUEQ) Partnership was established to gather, generate, and promote best available technologies and design practices for climate and air quality resilience in UK cities relative to the building services engineering sector. This is a working group of CIBSE Resilient Cities Group in partnership with UK Wind Engineering Society.

UKUEQ consists of over 20 organizations from industry and academia who support the generation of publications and hosting of events. One primary aim is to generate a better insight on urban environmental quality through urban physics and integrated digital tools with computational fluid dynamics (CFD) at its centre. During the CIBSE Build2Perform Live event in December 2023, the group hosted a session called 'Advances in urban digital planning and modelling for climate resilient, healthier urban areas and buildings.' Later this year the group will be co-hosting mini-symposia at University of Birmingham and University of Southampton followed by Build2Perform Live.

For more details on UKUEQ and its activities see www.cibse.org/ukueq.

CIBSE Journal article:
The CIBSE Journal (June 2024) published an article called ‘The urban emergency’ which was based upon this White Paper.

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