Written evidence submitted by Dr Eric Laurentius Peterson (Visiting Research Fellow, University of Leeds)

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Heat resilience and sustainable cooling

The Environmental Audit Committee is undertaking a short inquiry into ***heat resilience and sustainable cooling***. It will look at the relationship between heat and health; examine the adequacy of current Government policies in relation to current and future need for cooling; and consider what measures could be taken to increase adaptation and resilience to rising temperatures. It is seeking written evidence to inform its inquiry and will hold an oral evidence session in order to form an initial view of the issues.

Re: Health impacts, Air-conditioning, and Government action

I am Dr Eric Laurentius Peterson, M-CIBSE, CEng, Professional Engineer (Mechanical and Environmental licenced in as required to practice in certain US states as well as Australia), Visiting Research Fellow (Bioclimatic Design) at the University of Leeds, and Secretary of ASHRAE Technical Committee TC 4.2 Climatic Information. The reason I am submitting evidence is mainly to advocate for appropriate consideration of the combined impact of heat and humidity during heat waves, rather than the current practice of arbitrary reaction to the "dry-bulb" temperature typically reported by the media. Figure 1 illustrates that non-air-conditioning solutions are ***sufficient*** under shade if relative humidity is low .

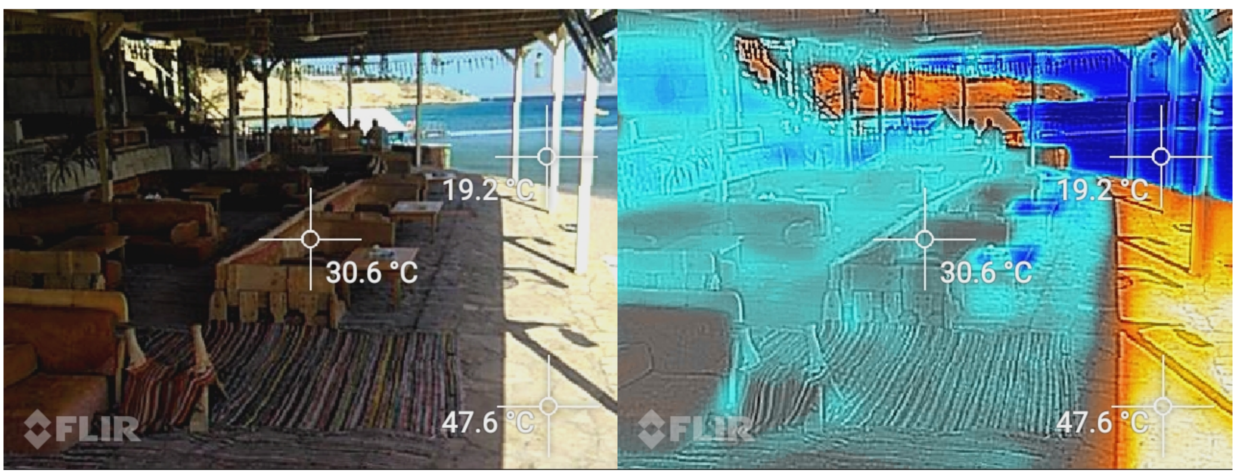

Figure 1: A thermal image (early afternoon 12th April 2022) Illustrates a sufficient alternative to air-conditioning provides shade, while open to views and provided with ceiling fans – designed and managed by Sinai Bedouin people at Sharks Bay Ombi resort in Sharm el-Sheikh – while relief from extreme heat events is available by water sports and showers. On the other hand, it must be stated that guests' rooms have air conditioning as Egyptian heat and humidity is more extreme in summer.

In summary, I recommend that the UK government adopt the Sufficiency-Efficiency-Renewable framework to adapt buildings in a changing climate without compounding the problem [1]. The SER framework includes sufficiency, which tackles causes of environmental impacts by avoiding demand for energy and materials over the building lifecycle, efficiency, which tackles symptoms of environmental impacts by improving energy and material intensities, and renewables, which tackles consequences of environmental impacts by reducing carbon intensity of energy supply. The SER framework introduces a hierarchical layering, sufficiency first followed by efficiency and renewable, which reduces the cost of constructing and using buildings without reducing the level of comfort of occupants. For example, building fabric measures improve heat retention in winter, and low-energy measures improve coolth in summer.

Please find the following responses addressing each of the issues raised in the terms of reference

1. **What evidence exists on the relationship between heat and human health (mortality and morbidity), and which communities are worst affected?**

People (and horses) are unique among mammals in our ability to regulate body temperature by secreting brackish water from millions of sweat pores in our skin. Consequently, we can thrive in hot climates if we find shade from the noon-day sun, rest, and drink sufficient water balanced by electrolytes – as long as our sweat continually evaporates – a process limited by humidity.

Beware human beings cannot tolerate a wet-bulb temperature over 35°C (95°F) for long [2]. Wet-bulb is the evaporative temperature of an object soaked in water. Thermal health and safety can be measured by a combination of dry- and wet-bulb temperatures as well as exposure to radiation with the "wet bulb globe temperature" (WBGT). WBGT is weighted 70% by wet-bulb temperature while the dry-air temperature that is reported by media is only a small factor in the overall measure of heat stress.

Peterson [3] showed that 25°C (77°F) mid-morning wet bulb globe temperature in shade ($WBGT_{shade}$) is congruous with the "deadly curve" [4] where previous researchers compared mortality with mean daily temperature and relative humidity in a global analysis of mortality. This threshold lumped together all communities. Meanwhile the most vulnerable are exposed to noon-day solar radiation, afternoon maximum temperature, and persistent thermal radiation into the evening – especially in urban heat islands. A more strategic analysis is to assess maximum exposure of humans based on the WBGT-index developed 70 years ago at US Marine Corp Recruit Depot on Parris Island, South Carolina, USA [5], and since codified by ISO standard 7243 [6]. Occupational exposure at 30°C (86°F) WBGT might be managed by increasing hydration and rest breaks in response to physical demands [7, 8], yet vulnerable members of the community may not be sufficiently acclimated or physically fit to endure such conditions.

2. **How can sustainable cooling solutions and adaptation strategies be implemented in such a way as to minimise overheating, reduce energy consumption and prevent overloading of the electricity grid during peak demand?**

In oceanic climates such as that of the UK, passive cooling strategies can effectively minimise overheating. Only since summer 2023 have new dwellings in England been required to comply with Building Regulations Part O (Overheating), but this has the potential to guide renovation of existing dwellings [9]. Furthermore I suggest that the British public would be better informed if the coincident wet-bulb temperature was displayed together with dry-bulb temperature, because air-conditioning is probably not desirable if the indoor wet-bulb is below 20°C (68°F) so long as sunshine can be stopped by either external shutters or awnings before impinging on south- and west-facing windows. A high wet bulb globe temperature is much more important in deciding whether air conditioning is needed than the dry-bulb temperature that news media report. Ideally the public should also be warned of the likely maximum "wet bulb globe temperature" (WBGT equation 1[5, 6]) during summer.

$$WBGT = 0.7 \times T_{nwb} + 0.2 \times T_{globe} + 0.1 \times T_{air} \qquad \text{(equation 1)}$$

WBGT is most strongly influenced by the wet-bulb-temperature as the above equation applies 70% weighting to the "natural wet bulb temperature" (T_{nwb}) measured with an evaporatively cooled thermometer in a wet-wick, and 20% weighting on the mean radiant temperature measured with a lamp black globe (T_{globe}). WBGT is only marginally influenced by the dry-bulb air temperature (T_{air}) that is measured in shade as it would be reported by the Met Office only contributes 10% weighting to the WBGT index – because convective heat transfer is an order of magnitude less important that the dynamics of evaporative cooing versus radiation exposure.

My research identified where air-conditioning is a necessity [3]: essentially, when there are ten days per year where the maximum outdoor WBGT in shade exceeds 29°C (85°F), where the combined stress of heat, radiation and humidity are summarised by equation 1 above.

When people are sheltering under effective shade $WBGT_{shade}$ is simplified by equation 2 [10] on the assumption that the mean radiant temperature approaches the dry air temperature reported by the Met Office ($T_{globe} = T_{air} = T_{db}$) and the "natural wet bulb temperature" approaches the thermodynamic wet-bulb temperature ($T_{nwb} = T_{wb}$) which can be calculated from Met Office observations.

$$WBGT_{shade} = 0.7 \times T_{wb} + 0.3 \times T_{db} \qquad \text{(equation 2)}$$

"shade WBGT is calculated for an environment shaded from direct (and strong reflected) solar radiation and where surfaces are not significantly hotter or colder than the indicated air temperature"[11]. These conditions can be achieved by the best available passive architectural design as well as shade trees [12].

3. **What actions can be taken to protect those most vulnerable to the impacts of extreme heat?**

Unfortunately, there are sun-drenched streets flanked by buildings on both sides (known as urban canyons) where weather stations are not installed so the magnitude of problem is uncertain, and also there are unknown conditions inside of badly designed buildings that become overheated. In such places, occupants might need to escape to an air-conditioned shelter or find sanctuary in a wooded park. Vulnerable immobile individuals should be provided with bedroom air-conditioning under the sort of public health programs operating in New York City targeting those citizens who are deemed to be susceptible to the effects of extreme heat and humidity [13].

4. **To what extent do the Government's Climate Change Risk Assessment and National Adaptation Programme (as well as other related strategies such as the Net Zero Strategy and Heat and Buildings Strategy) identify and address the risks from extreme heat? (Note: The third NAP, covering the five-year period from 2023-2028, was published 17 July 2023)**

NAP3 makes no mention of humidity anywhere, but headline quotes Met Office Chief Scientist, Professor Stephen Belcher "Summer temperatures above 40°C, seen for the first time in July 2022, will become more commonplace by the end of the 21st century". So, I suggest we dig deeper into the single instance when the UK reached or exceeded 40°C shade air temperature, as illustrated in Figure 2.

LAST YEARS WEATHER HISTORY AROUND 20 JUL 2022

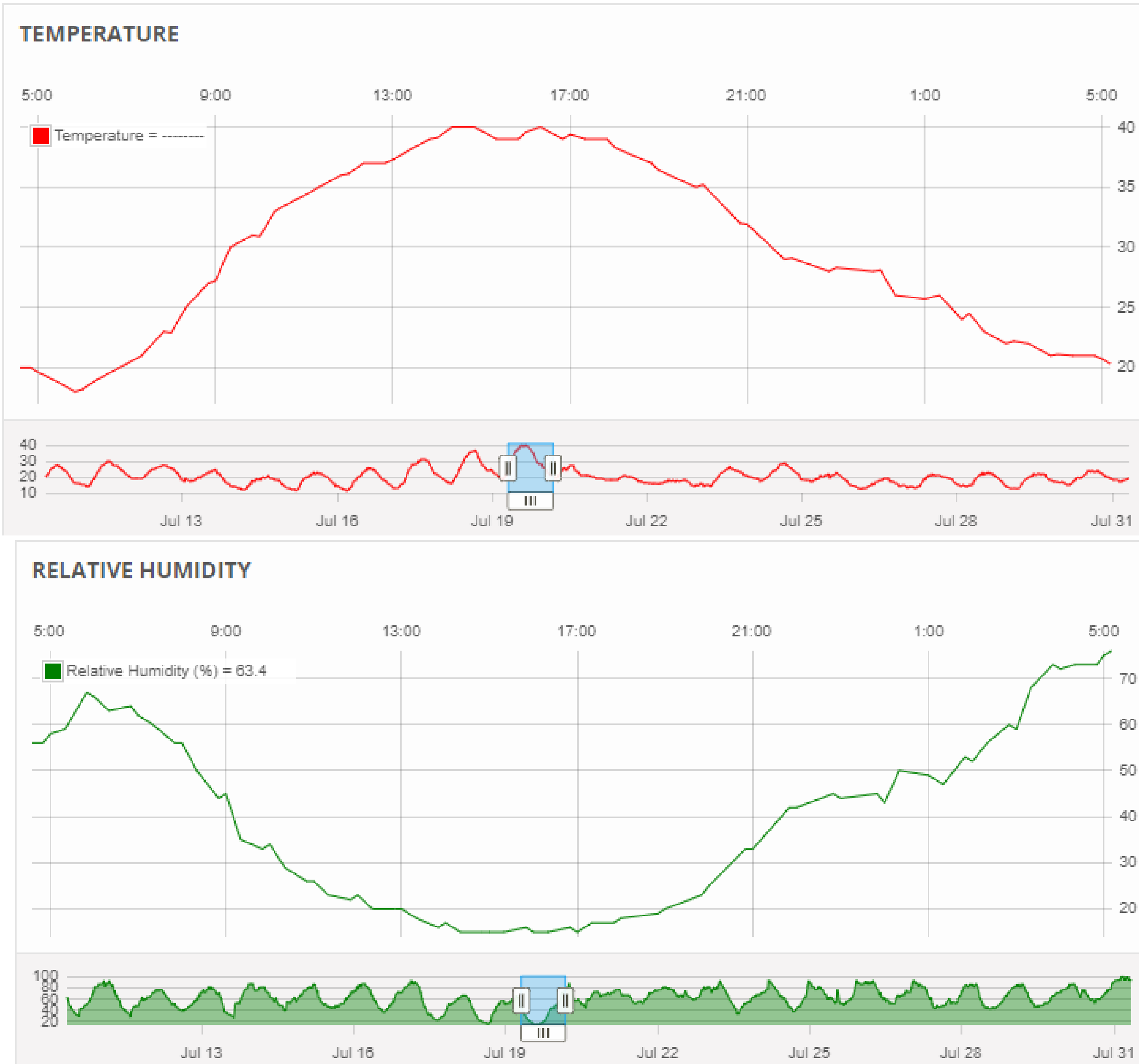

Figure 2 Coningsby Royal Air Force Base (accessing "last years observations" weatherhq.co.uk 20 July 2023) https://www.weatherhq.co.uk/weather-station/coningsby-royal-air-force-base/last-year maximum dry bulb temperature observations ≥40°C from 2:20 to 4:20 PM while elevated barometric pressure slightly declined from 1009 to 1008 hPa and relative humidity varied from 15% up to 16%. Note that the concurrent wet bulb temperature was about 21.1°C (70°F) using NOAA's "Dewpoint and Wet-bulb from Relative Humidity" calculator https://www.weather.gov/epz/wxcalc_rh and so conditions in shade approach 26.9°C WBGT for only a couple of hours (0.7×21.1°Cwb+0.3×40.3°Cdb = 80.4°F WBGT).

On the only day temperature ever reached 40°C in the UK, air-conditioning was not necessary if people rested in shade and hydrate during such brief events. My children were just fine that afternoon, let out of school at 3 PM just as the dry-bulb mercury touched 40°F. So, I recommend that NAP3 guide the Met Office and media should forecast likely wetbulb and WBGT in shade together with dry bulb temperature.

On the other hand, NAP3 correctly mentions that Building Regulations Approved Document O has been added to limit new residential buildings' exposure to excess heat and unwanted solar gains. For non-residential buildings, NAP3 mentions reasonably suggests that overheating can be well managed through established strategies, including mechanical ventilation and air conditioning, but does not suggest what should be done if the electricity network were overloaded during an extreme heatwave.

NAP3 suggests the forthcoming Housing Health and Safety Rating System review may inform mitigation of excess heat in existing residential accommodation with regulations to be developed circa year 2030.

NAP3 also suggests that government will develop measures to deliver net zero retrofit to existing homes and non-domestic buildings and to concurrently minimise risks of overheating these buildings. They intend to commission targeted research into "which building types, tenures and groups are most at risk and likely to be impacted". They also aim to raise "public awareness of the risks and adaptation actions citizens can take". They will "commission research to close evidence gaps identifying the buildings most vulnerable to extreme heat and where these are located, as well as appropriate adaptation solutions".

NAP3 suggests that winter heating energy efficiency retrofits increase the importance of ensuring adequate ventilation in summer, calling for research to identify which building types are more at risk of overheating, and discover "proportionate interventions to address this risk, and priorities for action".

5. **Does the current planning framework do enough to encourage heat resilience measures such as cooling shelters, water bodies, green infrastructure and shading to be integrated into urban planning? Where such measures are incorporated, how accessible and successful are they?**

During the past winter of extreme energy price rises, local government and charities have done a great service to the vulnerable members of the community by providing "warm spaces". So, it would seem reasonable to expect such premises could also serve as cooling shelters – except that air-conditioning could eventually become truly necessary if IPCC reports are ignored by the governments of the world. Fortunately for the Global South, the UK and nearby nations will be discouraged from retrofitting buildings with air-conditioning as they are typically heated with hydronic hot water radiators, rather than ducted forced air-furnace systems typical of North America. Northern European and UK heating systems cannot generally be repurposed to operate as chilled-water cooling units, and so disruptive and expensive retrofitting with ducted air-conditioning could become necessary to provide effective cooling shelters. A more cost-effective solution would be to invest in green infrastructure and shading. The efficacy of blue and green infrastructure is well established [14]. Unfortunately, although water bodies provide tremendous heat relief to bathers, the persistent pollution of British rivers and coasts with raw sewerage recommends against "wild swimming", and so energy-intensive chlorinated swimming pools are the one form of "blue" infrastructure that could serve as a reliable public health measure.

6. **What can be done to protect the UK's existing public and private sector housing stock from the impacts of extreme heat while ensuring that homes are sufficiently warm in the winter months?**

Building Regulations Approved Document O provide a framework that might suggest which existing housing stock needs retrofitting to prevent overheating. Based on my experience rating the heating and cooling loads of dwellings throughout Australia, I agree with NAP3's suggestion that winter heating energy efficiency retrofits increase the importance of ensuring adequate ventilation in summer. But I further recommend the retrofitting of shading devices outside the building envelope that admit winter sun, and are also aligned to intercept the rays of the sun during summer.

I have found that balanced solutions can be achieved in a process of iterative design modelling the particulars any client's building project by employing CSIRO's NatHERS, the US Government's EnergyPlus, or one of the UK's proprietary building modelling software packages that utilise 8760 hour typical meteorological year or test reference year data.

7. **What role might reversible heat pumps (which can act as both heating and cooling systems) and other emerging technological solutions, such as the development of smart materials, play in meeting future cooling demands?**

Reversible heat pumps are not a practical solution for retrofits because UK buildings are typically heated with hydronic hot water systems connected to a gas boiler. A current policy theme has been that these gas boilers could be rapidly replaced with either a heating-only heat pump[15], or more gradually by connection to district heating network (DHN) in situations where the local business case has succeeded [16]. Unfortunately for reversible heat pump sales teams, a puddle of cold condensate would appear in summer If a hydronic radiator were connected to a reversible heat pump (or district cooling network). Consequently, installation of reversible heat pumps would only be practical as part of a ducted air-conditioning system, with integrated fan-coil with integrated condensate drainage system. Such retrofits would be much more expensive and disruptive than fitting external solar control systems. An example "smart material" that has been proven to avoid unwanted solar heat gain are "cool roof" coatings [17]. Passivhaus approaches to energy-recovery ventilation have the potential to minimize overheating so long as fresh air night purging could be enhanced and special attention is given to restrict solar gain during summer.

8. **How can cleaner refrigerants with low or zero global warming potentials support the UK's cooling needs while contributing to the national emission reduction targets?**

Conventional air conditioners and heat pumps compress refrigerant vapours such as hydrochlorofluorocarbons (which are greenhouse gases thousands of times more powerful than carbon dioxide if they leak into the atmosphere), consequently the adoption of natural zero global warming potential refrigerants such as propane would certainly improve national emissions. Safety issues would recommend that such equipment be packaged outdoor chiller (or reversible as hot water generator) units, or by connection to a district chilled water network where vapour-compression cooling plant are regularly serviced by skilled technicians.

9. **Does the Government's Future Homes Standard adequately consider overheating in homes? If not, what additional elements should it include?**

Outdoor cooking during hot weather could be incentivised, as is the case in Australia where covered balconies fitted with lighting, ceiling fan, and BBQ typically adjoin dining rooms so that heat and smoke can be excluded from the building envelope. Vernacular architecture in many tropical countries involve the provision of an detached cook-house to product the central dwelling from heat (and fire risk) of cooking.

10. How effectively is the Government working across departments and with local authorities to ensure a coordinated approach is taken to heat resilience?

Local governments in the UK are not well resourced to deal with inspection and enforcement of safety of existing dwellings in terms of damp mold and cold drafts, so they would likely be struggling to ensure overheating is also manageable. More effective local government action has been exemplified in affluent North American cities such as Chicago and New York, but these cities have local taxation and regulatory powers exceeding their respective state government administrations.

11. Does the UK need a dedicated Heat Resilience Strategy? What lessons can be learned from other nations when it comes to national strategies for heat resilience?

As stated above, strong local governments of affluent North American communities offer exemplars. Japan provides an excellent national approach to summer time heat stress management, including but not limited to "Heat Illness Prevention Information: Current WBGT and Forecast" https://www.wbgt.env.go.jp/en/

July 2023

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