Part I: Setting out the issue
Definitions and causes of poor indoor air quality and overheating in homes

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UCL Institute for Environmental Design and Engineering (IEDE), The Bartlett, University College London (UCL)
1 Causes of indoor overheating

Homes in urban environments are expected to experience an increased risk of indoor overheating in the future due to the combined effect of:

• climate change (macroclimate)
2 Causes of indoor overheating

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- climate change (macroclimate)
- urban heat island (mesoclimates)

(UCL IEDE LUCID project, doi: 10.1177/0143624410394530)
3 Causes of indoor overheating

Homes in urban environments are expected to experience an increased risk of indoor overheating in the future due to the combined effect of:

- climate change (macroclimate)
- urban heat island (mesoclimate)
- changes in the properties of local surroundings (microclimate)

(Virk et al. 2014, DOI: 10.1177/1420326X14527976)
4 Causes of indoor overheating

Homes in urban environments are expected to experience an increased risk of indoor overheating in the future due to the combined effect of:

- climate change *(macroclimate)*
- urban heat island *(mesoclimate)*
- changes in the properties of local surroundings *(microclimate)*
- changes in the properties of individual buildings *(indoor climate)*

(Homes and Communities Agency ENEWorkshop – Overheating and indoor air quality in new homes
Anna Mavrogianni, UCL IEDE

\(\text{Arup 2014, publications.arup.com/Publications/R/Reducing_urban_heat_risk.aspx}\)
5 Causes of indoor air pollution

- Space heating
- Cooking
- Smoking
- Building materials and furnishings (asbestos, flame retardants, etc.)
- **Household products** (cleaning, DIY, etc.)
- **Radon** (from soil)
- **Dampness and mould**
- **Pathogens** (bacteria and viruses)
6 Causes of indoor air pollution

The following **building characteristics** can result in higher levels of **indoor air pollution**:

- Small rooms
- Non-working/unused kitchen extract and MVHR fans
- Location of home (ventilating a home by opening windows and doors in areas of high levels of outdoor pollution)
- Overcrowding
7 Other drivers of poor indoor air quality and overheating?

The facts
80% UK legally binding decarbonisation target by 2050
27% of UK energy consumed in dwellings
85% of existing dwellings will still be standing in the 2050s
only 1% of which have adequate thermal performance

The challenge

2016-18 2020 2030 2040 2050
2015
eradication of fuel poverty
smart meters in all UK homes, ‘whole house’ retrofit package to 7 million houses
implementation of all cost effective measures
1+ home fully retrofitted every minute for the next 10 years!
zero carbon stock?
8 Definitions of indoor overheating

Overheating can be assessed with respect to:

- Thermal comfort
- Health
- Productivity
9 Definitions of indoor overheating: comfort

Of the three forms of definition, the most commonly applied in the design of buildings is **thermal comfort**.

Thermal comfort itself has been defined in a number of ways using ‘**static**’ and ‘**adaptive**’ models.

The ISO Standard 7730:2005 defines thermal comfort as ‘**that condition of mind that expresses satisfaction with the thermal environment**’.

### ‘Static’ approach

<table>
<thead>
<tr>
<th>Building type</th>
<th>Peak temperature (°C)</th>
<th>Overheating criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices</td>
<td>28°C</td>
<td>1% annual occupied hours over peak temperature</td>
</tr>
<tr>
<td>Schools</td>
<td>28°C</td>
<td>1% annual occupied hours over peak temperature</td>
</tr>
<tr>
<td>Homes - living areas</td>
<td>28°C</td>
<td>1% annual occupied hours over peak temperature</td>
</tr>
<tr>
<td>Homes - bedrooms</td>
<td>26°C</td>
<td>1% annual occupied hours over peak temperature</td>
</tr>
</tbody>
</table>

Peak temperatures and overheating criteria for the design of buildings
(CIBSE Guide A Environmental design)
10 Definitions of indoor overheating: comfort

The BS EN 15251:2007 Standard introduces the concept of ‘acceptable’ indoor comfort temperatures as a function of the running mean of outdoor temperatures. The classifications relate to the ability of the occupants to modify their environments.

‘Adaptive’ approach

Indoor comfort temperatures for free running buildings as a function of the running mean outdoor temperature (building type I: spaces occupied by vulnerable people, II: existing buildings, III: new buildings)

(BSI 2007, BS EN 15251:2007)
11 Definitions of indoor overheating: health

Despite the wealth of epidemiological studies that demonstrate a strong relationship between external temperature and excess heat-related mortality, there are currently no established, universally accepted upper internal temperature thresholds for health.

External temperature thresholds of heat-related health effects

Temperature-mortality associations in each region in England and Wales
(RR: Relative Risk)

(Armstrong et al. 2011, DOI: 10.1136/jech.2009.093161)
12 Definitions of indoor overheating: health

The Heatwave Plan for England defines alert levels based on the exceedance of threshold maximum day and night temperatures defined by the Met Office National Severe Weather Warning Service (NSWWS) region.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Long-term planning - All year</td>
</tr>
<tr>
<td>Level 1</td>
<td>Heatwave and Summer preparedness programme - 1 June – 15 September</td>
</tr>
<tr>
<td>Level 2</td>
<td>Heatwave is forecast – Alert and readiness - 60% risk of heatwave in the next 2 to 3 days</td>
</tr>
<tr>
<td>Level 3</td>
<td>Heatwave Action - temperature reached in one or more Met Office National Severe Weather Warning Service regions</td>
</tr>
<tr>
<td>Level 4</td>
<td>Major incident – Emergency response - central government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health</td>
</tr>
</tbody>
</table>

Heat alert levels
(PHE NHS Heatwave Plan for England 2015)

<table>
<thead>
<tr>
<th>NSWWS Region</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>London</td>
<td>32</td>
<td>18</td>
</tr>
<tr>
<td>South East</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>South West</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Eastern</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>West Midlands</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>East Midlands</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>North West</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Yorkshire and Humber</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td>North East</td>
<td>28</td>
<td>15</td>
</tr>
</tbody>
</table>

Regional thresholds
(PHE NHS Heatwave Plan for England 2015)
13 Definitions of indoor overheating: productivity

Adverse heat stress effects could range from a **reduction in work productivity levels** to **risks in health and safety**. The most commonly used occupational heat stress index is the **Wet Bulb Globe Temperature (WBGT)**.

**Impact of heat on productivity**

Approximate estimates of limiting WBGT thresholds for the % percentage of a working hour needed for rest due to heat exposure for different activity levels for an average acclimatised worker wearing light clothing assuming no sensible air movement

14  Definitions of indoor overheating

**Combining thresholds**

Selected temperature thresholds relevant to London’s urban systems

Definitions of poor indoor quality

WHO guidelines provide a scientific basis for legally enforceable standards for indoor air quality. Guidelines focus on air pollutants that are often found indoors in concentrations of health concern.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Units</th>
<th>Short-term exposure</th>
<th>Annual average exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>(μg/m$^3$)</td>
<td>25 (24-h mean)</td>
<td>10</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>(μg/m$^3$)</td>
<td>50 (24-h mean)</td>
<td>20</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>(μg/m$^3$)</td>
<td>200 (1-h mean)</td>
<td>40</td>
</tr>
<tr>
<td>O$_3$</td>
<td>(μg/m$^3$)</td>
<td>100 (8-h mean)</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>(mg/m$^3$)</td>
<td>100 (15 minutes)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>35 (1-h)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 (8-h)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 (24-h)</td>
<td></td>
</tr>
</tbody>
</table>

(WHO 2005, 2010)
Thank you | Any questions?