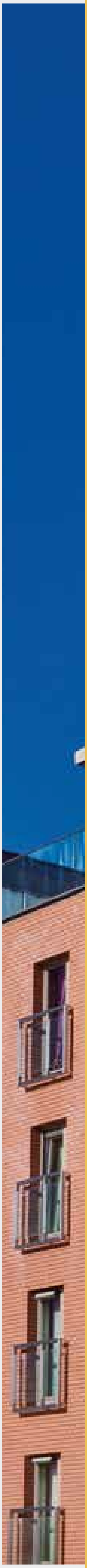
OVERHEATING IN HOMES

Keeping a growing population cool in summer

October 2015



OVERHEATING IN LONDON

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83% of Londoners suffered from uncomfortably hot homes this summer at least once

Only **13%** never suffered from overheating this summer

54% of Londoners say overheating would influence their decision when buying a home

8% of Londoners affected have taken action and installed air conditioning

31% of those who suffered from overheating felt unwell or tired

52% of those who felt uncomfortably hot this summer were woken up in the night

WSP | PARSONS BRINCKERHOFF

FINDINGS FROM A SURVEY OF 1,005 LONDONERS

The survey was conducted by ComRes as part of WSP | Parsons Brinckerhoff's wider research paper into overheating in homes, which will be launched 22 October.

2,000 **deaths** are caused by overheating each year, according to government figures.

The UK's temperature will potentially **increase 2.5°C** by 2050.

EXECUTIVE SUMMARY

Britain urgently needs to put in place plans to reduce the risk of homes overheating. 80% of Londoners we surveyed said they suffered from overheating in their homes this summer. One in ten said their homes were uncomfortably hot most of the time. Temperature logging in homes shows that temperatures regularly exceeded generally accepted temperature thresholds.

This problem is going to get worse.

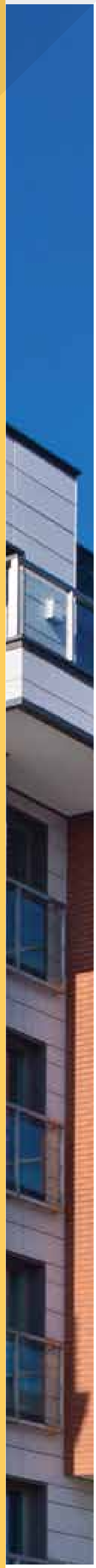
Tighter Building Regulations have improved insulation – reducing energy bills and greenhouse gas emissions. We also generally design homes to have good levels of daylight which makes them a more pleasant place to be. More insulated homes with higher amounts of glazing mean it can be more difficult to keep homes cool. To add to this the projections are that summer temperatures will increase significantly.

Overheating matters:

- Hot Londoners say they can't sleep and that this affects the capital's health and productivity.
- Overheating is becoming a material factor in Londoners' house hunting.
- Retrofitted cooling systems may become mainstream creating more electricity demand. Already 8% of Londoners affected in our survey have installed cooling.
- At worst, thousands of people already die from overheating each year – although not as many as from the cold.

In our report we suggest five steps that can be taken to reduce overheating:

1. **Develop a robust regulatory overheating analysis method for all new developments.**
2. **All new housing developments to adhere to a 'cooling hierarchy'.**
3. **All new buildings to be designed to facilitate retrofitted cooling installation.**
4. **Measures should be introduced on new developments to reduce the Urban Heat island.**
5. **The "all-electric city" should become a wider priority - reducing heat production from vehicles and buildings in urban areas.**



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OVERHEATING

WHAT CAUSES IT, WHY DOES IT MATTER?

WHY ARE WE CONCERNED ABOUT OVERHEATING IN HOMES?

Overheating is a problem that's going to get worse for Britain's homes.

- **Tighter Building Regulations have made homes more energy efficient.** As a result, new builds require much less energy to create a safe and comfortable environment for occupants; significantly reducing bills, improving health in winter and reducing deaths from the cold. Energy efficient homes are also playing a major role in the move towards a low-carbon society. These higher standards, however, combined with hot city temperatures increase the risk of overheating.

- **Climate change will increase peak temperatures.** Climate forecasts suggest that peak London temperatures will rise by 6.5°C by the 2050s. That's far beyond what we see today and may require a wholly different response.

- **A bad night's sleep affects health and productivity.** There are also concerns that productivity levels will diminish as more people find their sleep to be disrupted by high night-time temperatures. A study of 21,000 employees commissioned by Vitality Health found a strong correlation between a lack of sleep and reduced productivity.

- **Older populations are more susceptible to heat.** Britain's population is expected to increase to 77 million by 2050 and by 2065, the population of England and Wales over 65 years old will have risen from 18% to 26%. An expanding population would not just increase demand for homes, but an ageing population would mean that more are occupied by the most vulnerable sectors of society. Not only are the elderly more susceptible to illness, they are more likely to be at home during the hottest times of day.

- **We're building more flats.** The higher demand for housing and property prices are also likely to prioritise the building of denser flats over other dwelling types. This is significant because even though all types of home can experience overheating, flats tend to suffer to a much greater degree when temperatures rise. This is largely a ventilation and glazing issue. Flats are unable to have the same amount of air flow through as a house with many windows, but the glazing that they do have tends to cover as great an area as possible on one side of the building. The need to fit more people into smaller spaces will exacerbate this. Flats may get smaller, and more will exhibit design features that intensify overheating, such as single aspect design.

- **Very hot temperatures can kill.** Overheating in homes not only has the potential to contribute to discomfort, but could be the cause of significant health implications for residents. There were over 2,000 excess deaths during the 2003 heatwave, which saw temperatures in the UK remain above 30°C for a 9 day period. The young, elderly and those with pre-existing illnesses experience the greatest level of risk when temperatures rise, with dehydration one of the biggest killers. However, people who are usually fit and well are also likely to suffer deterioration in their quality of life or health.
- **We're building a future problem.** When overheating is considered from a purely financial perspective, we are presented with some major issues. In the future, homes may simply be uninhabitable, or at the very least, they will require very expensive retrofitting. New, modern homes could lose value as people avoid them in the future, perhaps in a similar way that people avoid 1960s tower blocks currently.

A number of different projects have recently studied the issue of overheating in homes. The NHBC, Zero Carbon Hub and DCLG have all undertaken research with common findings around the fact that the issue is significant, requires some form of quantification and design response in relative to different variables.

WHAT IS OVERHEATING?

Overheating can be discussed as a factor of thermal comfort, which has a supposedly simple definition; ‘that condition of the mind that expresses comfort with the thermal environment’. However, as each of us has a very different idea of what being too hot or too cold means, creating a simple threshold comfort level is virtually impossible. Other variables also need to be taken into account; the ability of an occupant to change clothing and open windows, the availability of cooler rooms and the vulnerability of an occupant, will all have an influence on an individual’s thermal comfort.

This creates a problem for the construction and property industry. Overheating risk is currently assessed using different criteria from one building to another. Currently, Building Regulations requires the use of SAP (Standard Assessment Procedure) to assess overheating in new homes; however there is overwhelming agreement within the industry that it is inadequate. It uses a basic methodology that is not realistic.

Some methods, such as CIBSE (Chartered Institution of Building Services Engineers) old Guide A, used absolute temperature thresholds; greater than 26°C in bedrooms and 28°C in living rooms for more than 1% of time. Others use an ‘adaptive comfort model’, as in the new CIBSE Guide A (linked to Technical Memorandum 52). In addition to the lack of clarity over guideline use, the fact that this method is not really designed for domestic buildings poses questions for their applicability within this setting. Until a more robust definition and evidence-based methodology is embedded within Building Regulations, we will struggle to tackle the issue of overheating.

There is no doubt that greater agreement upon an overheating definition, and methodology for assessing it will enable us to better avoid it.

WHAT ARE THE CAUSES OF OVERHEATING?

There are three primary sources of heat within a home:

External temperature

External temperature is a primary factor. This is something that we cannot control on an individual basis, but there a number of society wide actions which could be taken to help reduce city temperatures, as discussed later in this report.

In the UK whilst approximately 27,000 people suffer cold related deaths per year, only 2,000 people are currently dying as a direct consequence of high temperatures. Climate change projections suggest heat related issues are likely to rise. The south is likely to be disproportionately affected: During the 2003 heatwave 64% of total deaths occurred in southern regions. It is predicted that this area of the UK might see a temperature rise of between 2.3°C and 2.7°C by 2050.

Heatwaves, which are expected to increase in both frequency and intensity, also have implications for air quality. In 2003 it is estimated that 21-38% of total excess deaths were associated with increased ozone and PM10 levels. The health advice to protect oneself from the reduced air quality concurrent with a heatwave is to stay inside. However, if temperatures in the home increase as we are suggesting, this will not be a preferable option either.

Solar Gain

With our increasingly well insulated and less draughty homes, the demand for good levels of daylighting and consequent solar gain is becoming almost as important as external temperature. Shading, the time of day, season and type of glazing have an impact on this. Although solar gains are limited by regulation in commercial buildings, the same is not true in homes, nor may this be desirable.

Internal heat gain

Internal heat comes from electrical appliances, such as laptops, televisions, showers, chargers etc. and from occupants too. Between 1990, domestic electricity demand for consumer electronics increased by 77%, with two thirds of this rise occurring after 2000. This is projected by DECC to further increase in the coming years. In flats, energy lost from communal heating systems also contributes to internal temperature, exacerbated in some cases by poorly insulated pipework. Additionally, the longer people spend within a flat, the more their body heat will actively warm up the surrounding space. One of the biggest problems with internal gains is that they are hard to predict. Two flats built to exactly the same specification may be used in a completely different way.

In the past, many of these issues would not have emerged as homes were much draughtier and less well insulated and consequently less prone to overheating.

In addition:

Urban Heat Island (UHI) Effect: This describes the effect that causes urban areas to experience warmer temperatures than surrounding rural areas. The modification of land to harder, darker surfaces in cities leads to greater absorption of heat and less evapotranspiration (where heat energy is used to evaporate water from the surfaces of leaves or soil). The amount of energy reflected from surfaces in cities is 15% compared to 20-25% in rural locations . In addition, waste heat from vehicles and processes, and ironically, even the cooling systems used to try and combat the problem all contribute to higher temperatures in urban areas.

WHAT ARE THE CONSEQUENCES?

It is apparent that this is an issue that needs our immediate attention. Studies have suggested that around 20% of the current housing stock is overheating and this number is set to grow. There are also concerns that mortality levels will triple over the forthcoming years. Additionally, our research has shown that over half of Londoners are currently experiencing uncomfortable temperatures within the home. When future demographic and climate change influences are considered, this has the potential to be a massive issue.

This is not just a case of trying to limit the direct health risks associated with overheating. There is the potential for a number of environmental and economic consequences too.

- An increase in heat deaths and illness
- A decline in productivity owing to uncomfortable sleeping, working and learning environments
- Homes may suffer a reduction in value as they become less comfortable and desirable
- Increased demand for inefficient, dangerous and unattractive retrofitted cooling systems
- Increased peak energy demands
- Increased energy consumption and CO_2 emissions

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WE'RE OVERHEATING NOW

WHAT OUR RESEARCH SHOWS

We teamed up with polling company ComRes to survey 1,000 Londoners about their experience of overheating in their homes during this 2015 summer. We also conducted in-depth interviews of 22 Londoners living in London flats and also logged day to day temperatures over a two month period in their homes.

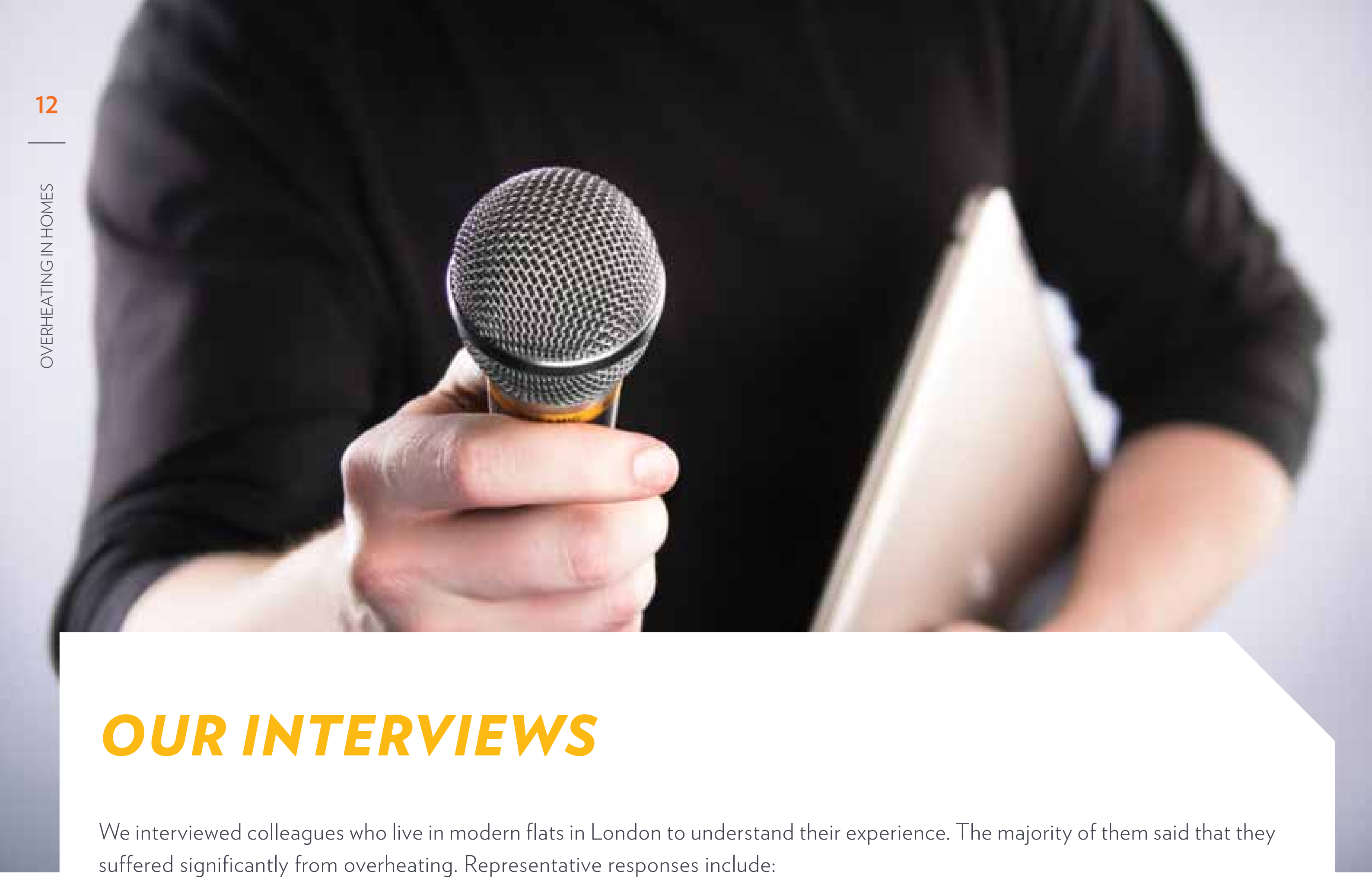
IN OUR SURVEY OF 1,000 PEOPLE

- 83% suffered from overheating in their home at least once in Summer 2015, 53% at least occasionally, 11% say their home was uncomfortably hot most of the time and 4% say this was the case all the time.
- Only 13% of Londoners never suffered from their home overheating in Summer 2015.
- Overheating affected residents in newer homes significantly more than residents in older homes.
- 54% say overheating would influence their decision when buying a home.
- 8% of Londoners whose home was uncomfortably hot in Summer 2015 have already taken action and installed cooling systems of some kind.

Our results show that the effects of overheating are being experienced by a considerable number of people living in the capital. 83% of people experienced at least some level of overheating, with just 13% experiencing no level of thermal discomfort during the summer period at all. It was also indicated that those in new build homes (82%) and single sided flats (70%) were most affected by overheating.

The 836 participants (83%), who had suffered from overheating to some degree, were then asked about the impacts this may have had on comfort and lifestyle. Over half of those surveyed had been awoken by uncomfortable night temperatures, and 40% described their sleep to be regularly disrupted. Additionally, when it is considered that nearly a third of people feel tired or unwell as a consequence of this, the negative health and productivity implications of overheating in the UK could be considerable. This helps explain why over half (54%) of Londoners are likely to consider the overheating potential of a home when purchasing a new place to live. The number was slightly lower when rental properties were considered (46%).

Occupants appear to have used a number of different techniques to combat overheating. The most popular coping mechanism was to sleep with the windows open (72%) but this may become less of an option in the coming years as densification is likely to place more homes in noisy areas, and rising external temperatures will reduce the effectiveness of window opening as a method of cooling down a room. In addition, one fifth of those surveyed avoided using heat generating appliances, such as washing machines or ovens in an effort to better manage the temperature within the flat. Most startling was the fact that 67 people (8%) had already installed cooling systems; an unexpectedly high figure considering the personal expense that this would have involved. It also lends evidence to the concerns that if the overheating problem is left unchecked in the forthcoming years, there could be a considerable increase in the uptake of potentially inefficient cooling systems.



OUR INTERVIEWS

We interviewed colleagues who live in modern flats in London to understand their experience. The majority of them said that they suffered significantly from overheating. Representative responses include:

- Showering and cooking in flats both caused peak uncomfortable temperatures for some:
  'If you have the oven on for half an hour or so then the flat gets really hot and the heat just doesn't go away.'
  This was found to be a problem regardless of the outside temperature.
  'Once you have had a shower, the temperature in the flat can get to above 30°C. It's uncomfortable.'
  'Once you've finished cooking you're so hot you don't want to eat.'
- The time of day was also significant:
  'It is not a pleasant environment to be in the middle of the day on a weekend.'

High night time temperatures affecting sleep were also cited as an issue:

- 'It got so hot last year that they had to have the windows open which means that when the trains start at 4am, your sleep is disrupted when you have to get up to close the window.'
- 'We leave the windows open until we go to bed as the high level of noise pollution means we can't leave them open.'
- 'I am unable to leave the windows open as I live next to a busy main road and the noise pollution is considerable. I cannot sleep at all without a fan…but I'm still woken up even with it.'

There are concerns that one of the economic consequences of overheating in homes could be a reduction in demand and value for overheating properties. In line with our ComRes survey most people said it would be a material factor in their decision making. For most it was a case of making sure that a new property had the appropriate opportunities in place to keep the temperature comfortable, such as ample ventilation.

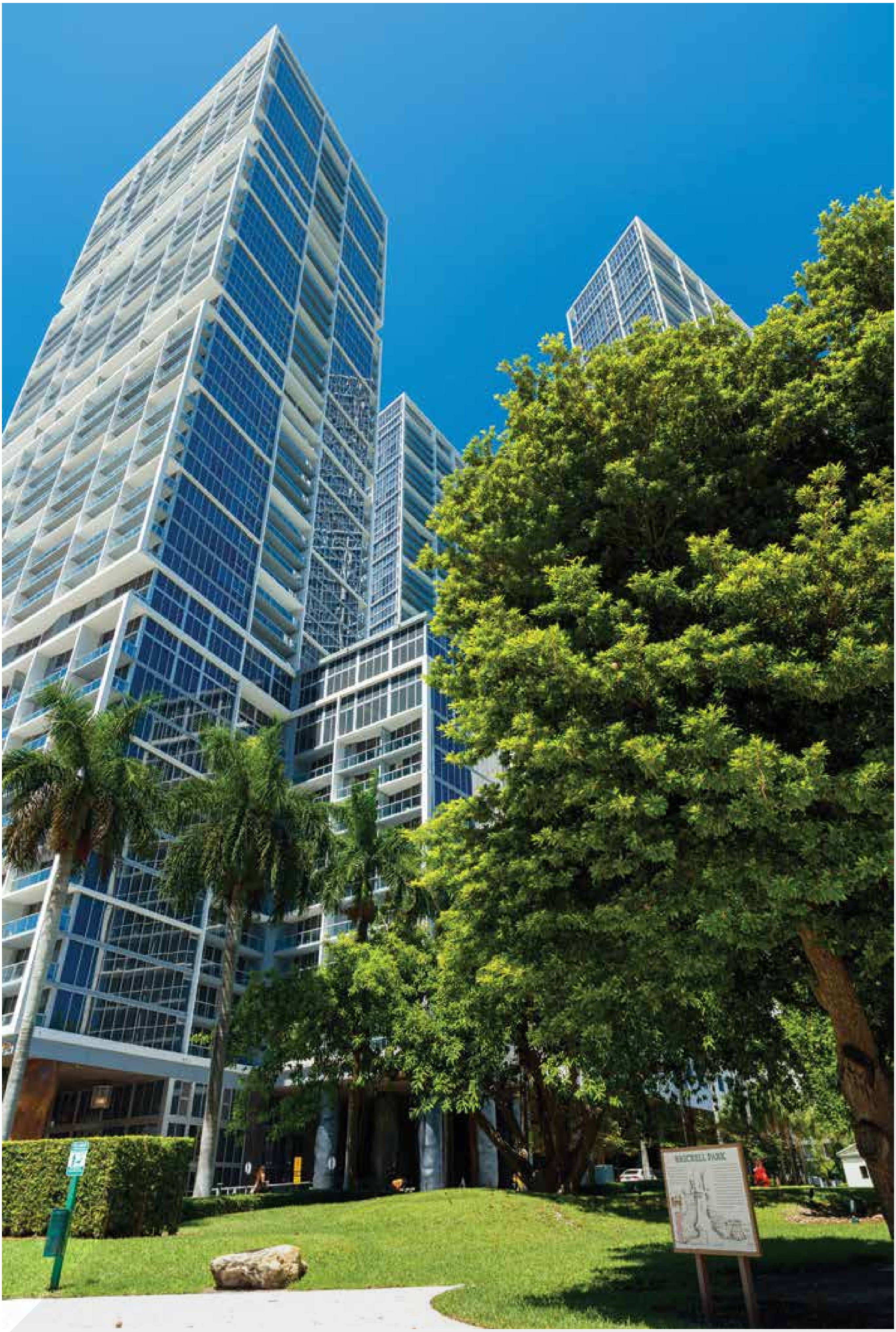
- 'I would be put off a building if there was no airflow.'
- 'I would consider the availability of window openings slightly more next time… would not go next to a railway line if possible.'
- 'The potential for a flat to overheat would influence my decision when looking, it wouldn't have done before I lived in this flat but now it definitely would.'
- 'It wasn't even something considered when getting this flat but now we would. It's just too hot and we can't cool it down.'

"ONCE YOU HAVE HAD A SHOWER, THE TEMPERATURE IN THE FLAT CAN GET TO ABOVE 30°C. IT'S UNCOMFORTABLE"

"IT GOT SO HOT LAST YEAR THAT THEY HAD TO HAVE THE WINDOWS OPEN WHICH MEANS THAT WHEN THE TRAINS START AT 4AM, YOUR SLEEP IS DISRUPTED WHEN YOU HAVE TO GET UP TO CLOSE THE WINDOW"

"THE POTENTIAL FOR A FLAT TO OVERHEAT WOULD INFLUENCE MY DECISION WHEN LOOKING, IT WOULDN'T HAVE DONE BEFORE I LIVED IN THIS FLAT BUT NOW IT DEFINITELY WOULD"

"WE LEAVE THE WINDOWS OPEN UNTIL WE GO TO BED AS THE HIGH LEVEL OF NOISE POLLUTION MEANS WE CAN'T LEAVE THEM OPEN"



MEASURING THE CURRENT TEMPERATURE IN HOMES

We put temperature loggers in 16 flats in London to get an idea of the extent of overheating in the homes of some of our colleagues. Of the flats 13 were built after 2006, 1 was built in 2000 and the other was retrofitted in the 1990s. Our data loggers were in place for a 6 week period, from mid-July to the end of August, taking measurements every 30 minutes.

At the end of this period, we analysed the temperatures against two standards; the old CIBSE Guide A and the new CIBSE TM52.

Old CIBSE Guide A

- Bedroom temperatures should not exceed 26°C for more than 1% of occupied hours.
- Living room temperatures should not exceed 28°C for more than 1% of occupied hours.

After testing all 16 data sets against the above criteria, we achieved the following results:

- >1/2 of the flats would have failed the 1% per year threshold for temperatures being above 26°C, despite the loggers being in place for a little over 6 weeks.
- The three worst performing flats exceeded the night threshold temperature for 43%, 34% and 28% of the studied time.
- The maximum living room temperature was exceeded much less frequently during this study, suggesting that the issue is less prevalent than overheating at night. Nine flats were greater than 28°C for more than 1% of the time during our study. This may be due to the fact that the participants were generally young professionals, leaving flats vacant in the day.
- The worst performing flats exceeded the living room threshold temperature for 3.72%, 3.52% and 3.41% of the studied time.

Additionally, we tested the flats against the new TM52 criteria, which stipulate:

- The amount of hours that the operative temperature can be exceeded.
- The maximum severity and frequency of overheating allowed within any one day.
- An absolute daily maximum, above which the level of overheating is deemed unacceptable.

After testing all 16 data sets against the above criteria, we achieved the following results:

- 9 of the flats failed 2 out of the 3 criteria, thus failing overall.
- Generally TM52 summer overheating would be calculated for June, July and August. As we only monitored for half of this time, there may have been further failings if the whole of this warmer time period was considered.

Overall, it is evident that the majority of the buildings were not performing as well as would have been expected. Nearly all of these homes have been built recently so it is a real concern that they appear to be creating quite such an uncomfortable thermal environment. However it is also clear that the results from the two different methods of analysis are quite different.

There was a much higher failure rate against the old Guide A than for TM52. This shows that the newer method is more lenient as it uses an adaptive thermal comfort model.

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OVERHEATING WILL BE A GROWING PROBLEM IN THE FUTURE

Effectively modelling overheating risk in new dwellings would be expected to reduce the number of at-risk buildings that are being developed.

In current regulations, the propensity of a dwelling to have high internal temperatures is covered in SAP Appendix P, and is calculated as follows:

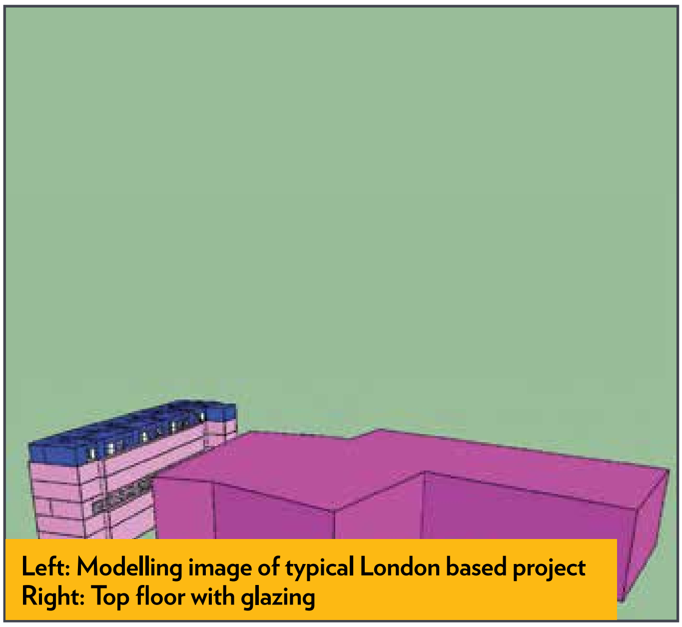
- The assessment, which is for the months of June, July and August creates a threshold internal temperature based on the following criteria:
- An assumption of air rate changes, determined by window opening opportunities.
- Heat loss through the building material.
- Summer gains, based on climate region and month- this is calculated in relation to area of windows and the amount of energy that can be transmitted through them.
- Internal gains are assumed to be the same as in winter, minus any gains from heating.
- A mean external temperature for the month and climate region.
- From this, the risk of overheating is then be defined as; not significant, slight, medium or high, depending on which bracket the calculated internal temperature falls into.

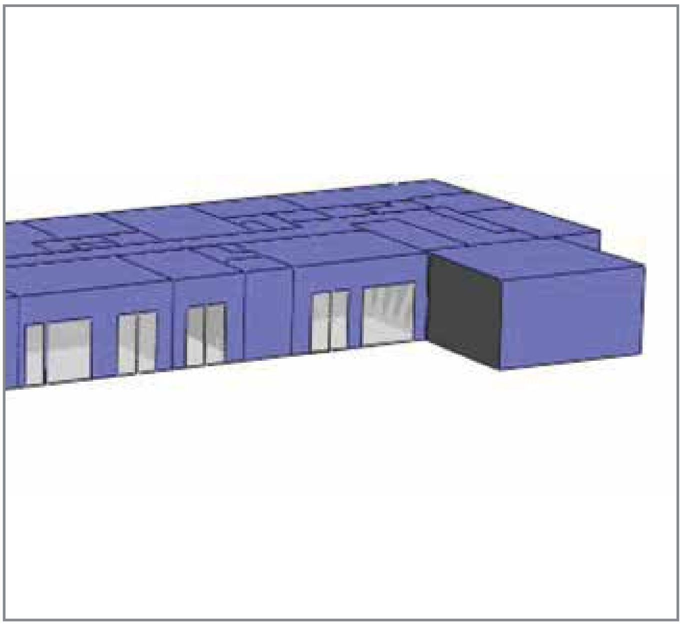
There is a widespread consensus that SAP generally underestimates the true extent of overheating considerably. As a static model, the results do not account for temperature and solar variability across the course of a day, instead using a monthly average. Equally, it makes very simplistic assumptions about ventilation and window opening, which may also contribute to unrealistic results. In fairness SAP's overheating analysis was only ever designed to be used for compliance, not as the design tool which many are using it for currently. Either way, it is in need of replacement.

The GLA requires major new developments in London are now required to demonstrate dynamic thermal modelling against the new CIBSE TM52 guidelines. To pass, buildings much adhere to at least two of the following three criteria:

- The threshold temperature (which is based upon running mean daily outside air temperature) must not be exceeded for more than 3% of occupied hours between 1st May and 30th September.
- The daily weighted exceedance relates to the severity of overheating within one day. This is a function of both temperature rise and the duration, and a daily limit for acceptability is set.
- An absolute maximum daily limit on a room is set, beyond which the level of overheating is unacceptable. The maximum daily limit is set as a component of the running mean outdoor temperature and the actual operative temperature within the room at any time.

To demonstrate the use of this method in calculating overheating risk, we have modelled a typical London based project comprising studio units and flats.





Left: Modelling image of typical London based project
Right: Top floor with glazing

The model requires the input of **assumptions** with regard to occupation, heat gains and sometimes openable window area. These are optional so figures are likely to vary between consultants.

London developments are also required to use the weather files stipulated in TM49: Design Summer Years for London, which look at hotter years as examples of more extreme events.

- London DSY05- the standard year.
- London 1976 baseline CIBSE TM49- consists of a long period of warmth.
- London 1989 baseline CIBSE TM49- represents a moderately warm summer.
- London 2003 baseline CIBSE TM49- consists of an extreme 2 week heatwave.

Additionally, to explore the potential influence of climate change on building performance we ran the following data sets, which are also recommended within TM49.

- 2020H: high scenario for emissions.
- 2050MH: medium/high scenario for emissions .

The model was run against the discussed criteria and the following results were achieved:

	London DSY05	1976 baseline CIBSE TM49	1989 baseline CIBSE TM49	2003 baseline CIBSE TM49	DSY 2020H	DSY 2050MH	DSY 2080MH
	Number of habitable rooms overheating						
Windows closed, blinds closed	21 of 43	24 of 43	22 of 43	27 of 43	22 of 43	22 of 43	24 of 43
Windows closed, blinds closed	22 of 43	28 of 43	27 of 43	28 of 43	22 of 43	24 of 43	30 of 43
Windows open, blinds closed	0 of 43	18 of 43	5 of 43	17 of 43	7 of 43	11 of 43	22 of 43
Windows open, blinds open	6 of 43	21 of 43	10 of 43	22 of 43	11 of 43	17 of 43	22 of 43

As there is only one scenario here which would have been considered a pass, we additionally ran the model with a number of other iterations to see if we could reduce overheating. These were:

- A lower g-value of glazing (The g- value represents the amount of solar energy that passes through the glazing). It should be noted that although a g value of 0.3 as used here as opposed to 0.5 would be possible, it may make it difficult to adhere to the threshold of thermal demand in SAP. Therefore whilst it may help the building to pass TM52, it could contribute to other regulatory failings.
- Brise soleil situated above the glazing. These have been modelled as 0.7 m in depth (see picture).

These alterations to the building design helped to achieve a much higher pass rate when analysed against our selected weather files for a second time. There are still significant failings for the 2050 climate projections, which would suggest that much more drastic measures would be necessary in future years. Yet even now, these passive specifications are not practical for all flats. Daylighting levels could be restricted by shading and for most developers and occupants, this would not be favoured. When windows cannot be assumed to be open for air pollution or noise reasons, modelling suggests that most modern flats will overheat.

	London DSY05	1976 baseline CIBSE TM49	1989 baseline CIBSE TM49	2003 baseline CIBSE TM49	DSY 2020H	DSY 2050OMH	DSY 2080OMH
	Number of habitable rooms overheating						
Windows closed, blinds closed Brise soleil*	0 of 43	9 of 43	0 of 43	10 of 43	0 of 43	9 of 43	18 of 43
Windows closed, blinds closed g-value = 0.3	0 of 43	10 of 43	0 of 43	5 of 43	0 of 43	0 of 43	9 of 43
Windows open, blinds closed g-value = 0.3 & brise soleil	0 of 43	0 of 43	0 of 43	0 of 43	0 of 43	0 of 43	2 of 43
Windows open, blinds open g-value = 0.3 & brise soleil	1 of 43	18 of 43	11 of 43	17 of 43	5 of 43	10 of 43	18 of 43

4

PRACTICAL SOLUTIONS TO MAKE BUILDINGS FUTURE READY

There a number of interventions which could be used to either reduce the extent of overheating or limit the impact that it is having on occupants. For any solution to be effective there is a need to consider cumulative effects. Some of these possible solutions are outlined below.

Ventilation

For heat to be removed there needs to be rapid replacement of warm air with cooler air. Opening all of the available doors and windows is the most obvious and effective method of doing this. For some this is not always an option; noise pollution, poor air quality, security and safety concerns can all restrict window opening.

Noise pollution is a big factor in limiting ventilation, affecting an ever increasing number of people as cities continue to densify and expand alongside railway lines and next to busy roads. It has been suggested that developments in areas heavily affected by noise pollution should be limited; but the very high demand for new homes makes this unrealistic.

Ventilation regulations are covered in Part F of the Building Regulations. Where natural ventilation is deemed not to be adequate mechanical ventilation is required.

Mechanical Ventilation

Mechanical ventilation is already required in kitchens and bathrooms, but when natural methods of ventilating the rest of the property are insufficient, mechanical solutions can be introduced to improve air movement. There are a number of different options available to do this, from extract only to more complex systems. Mechanical ventilation systems replace stale air with fresh, removing odours and excess moisture and aiding temperature control. This increases energy use, particularly in winter, when additional cold air may be introduced. Mechanical ventilation with heat recovery units manage this problem by using the outgoing air to warm the cold incoming air, which can then be bypassed in summer. Additionally, in flats with poor natural ventilation, the system would have to run at a very high rate to be able to achieve the recommended air changes, creating noise and again using a lot of energy.

Construction Details

In a new property there is the opportunity to adjust a number of building characteristics which would help to minimise solar gains:

Orientation: This will have a big influence on how much of the sun's energy can get into the building and will also affect the ease of heat removal. For example, a west facing building will not only receive greater solar gains at the hottest part of the day, but will experience higher external temperatures in the earlier evening, meaning purge ventilation will be less effective at this time. South and west facing buildings experience this problem to a much greater extent than north or east. Up to now designers have generally been encouraged to maximise south facing glazing to benefit from light and the free heat.

Glazing: The more glazing you have on a building, particularly if it is orientated towards the south, south west or west, the greater the solar gains will be. However smaller windows limit the availability of natural light and solar gains in winter and may mean that more energy is required for heating and lighting. Smaller windows are also not a popular choice with architects or occupants. Therefore a suitable balance between the two is necessary.

Advanced glazing technologies can be used to adjust the amount of light allowed in but these are expensive or where a lower g-value glazing is used, reduces the amount of daylighting unacceptably.

Shading & Shutters: Shading could also be used to limit solar gain in properties, with the type used determined by the window in question. For example, a south facing window would need protection from high level sun, which could be provided by projections or overhangs. For west facing, low level and vertical shading would work most effectively, but can restrict views. In order to allow for sufficient solar gains in winter and maintain the necessary energy efficiency standards, shading could be electronically controlled but this will be expensive and have significant maintenance implications. Mechanical units can also be retrofitted onto the side of existing properties. Shutters are also very effective at restricting solar heat gain within a flat and are also easily retrofitted, but again do completely eliminate the view.

Thermal Mass: Heavyweight building materials such as concrete and stone are able to store large amounts of heat when which acts to maintain constant building temperatures. For this to work, the heat that is stored in the building needs to be removed or 'purged' at night to make sure that this energy is gone before the next day. This works well in office buildings as the spaces are generally unoccupied at night and lots of cool air can be brought in to remove this energy build-up but this is much harder to achieve in a domestic setting and may exacerbate overheating in homes by pushing peak internal temperatures to the evening when most people are at home. In addition this is not practical on high-rise buildings where overheating is likely to be most prevalent.

Cooling

Mechanical cooling is an effective method of maintaining comfortable temperatures in homes. Although only 3% of houses currently have it installed, demand is increasing all of the time. It is also becoming more common, and even standard for new high end city-centre flats to have cooling fitted, as purchasers expect it. It has even been suggested by housing developers that some buyers will walk away from a flat which does not offer some form of mechanical cooling.

Fitting all new homes with mechanical cooling would help to promote safe and comfortable internal conditions. It should also reduce the number of occupants turning to 'cheap' portable or retrofit units, with high CO_2 emissions and unattractive design. Whilst, if well designed, it would save the cities from mirroring the aesthetics of your typical Mediterranean holiday resort, it is a solution that does not come without its drawbacks. For many, the cooling-as-standard approach is unnecessary. Cooling systems use a lot of energy and inevitably would increase overall energy use. Additionally, if cooling installation became the customary method to militate against overheating, it could limit the use of innovative building design in tackling the root causes of the problem.

Overheating is not yet critical enough to be necessitating that all new homes have cooling as standard, so an alternate solution could be to design buildings which allow for its easy installation at a later date. Providing a discreet area for an outdoor unit to be put in when deemed necessary would help to main attractive building façades. Additionally, ensuring that additional electricity demands could be supported would also be beneficial.

Active cooling may be the only answer in some situations and in the future, but it should be seen as a last resort. Efforts should instead be made to encourage the use of passive solutions within innovative building design.

Reducing the Urban heat Island Effect

Overheating in cities will accelerate in future years by the urban heat island effect (UHI), but there are some relatively simple changes that would make a big difference to the local environment. The inclusion of more green space, trees for shading and a reduction in tarmac would all help to lower ambient temperatures. As the external temperature is a driver for internal conditions, it would be expected to help to reduce overheating. Indirectly, the use of green infrastructure can improve air quality and levels of noise pollution, which may also allow more people to naturally ventilate their properties. A study in Manchester found that increasing the amount of green space by 10 per cent may restrict the predicted 2080 temperature rise for the city by 4°C .

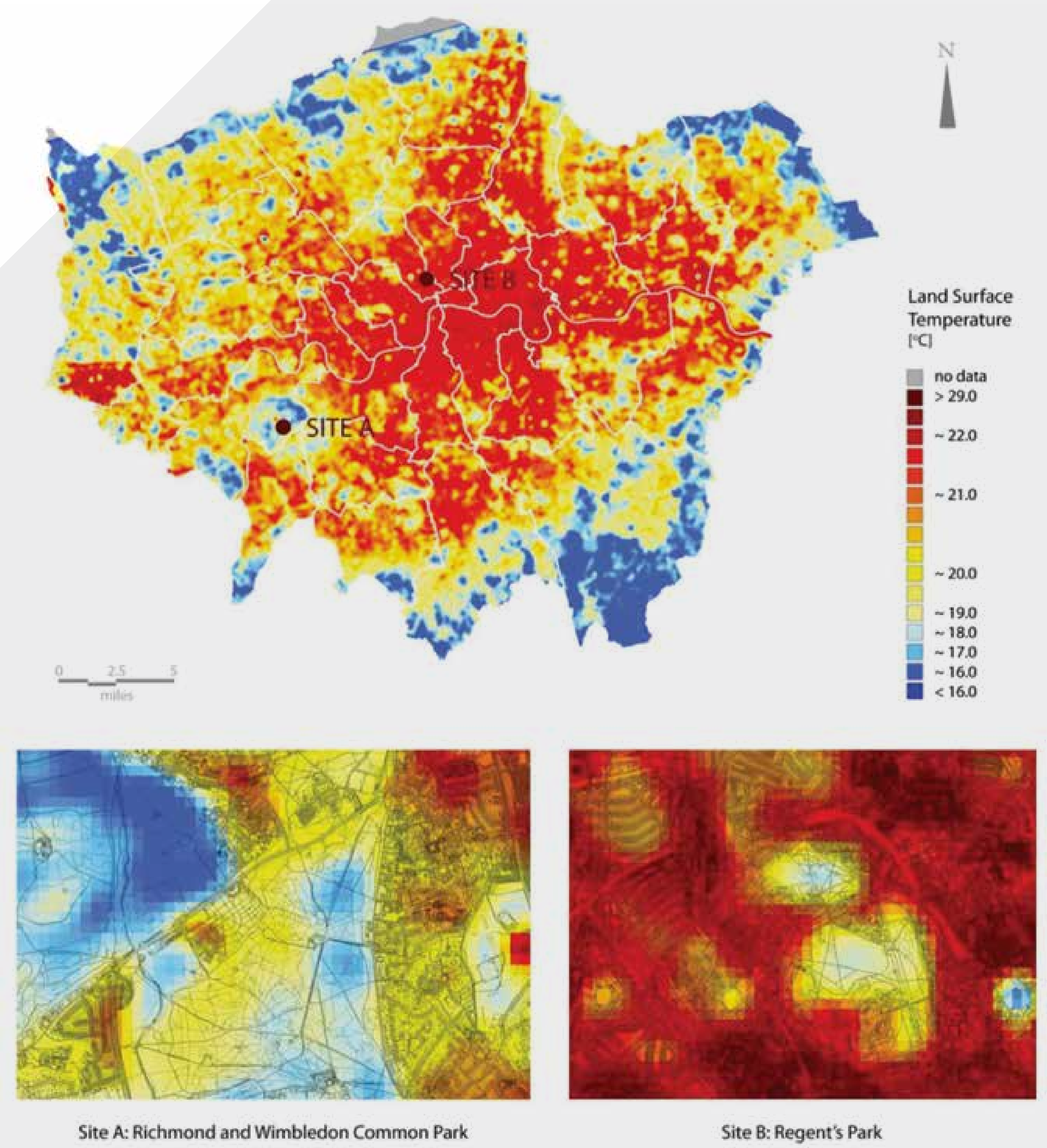
London is already taking steps towards the reduction of its UHI with the introduction of the All London Green Grid (ALGG). The objectives of this tie in well to 2.18 of the London Plan; 'enhancements to London's green infrastructure should be sought from development'. The ALGG aims to protect, conserve and enhance green space in London, and improve the use of and engagement with green infrastructure. Discussed below are some of the methods which could be utilised to lower city temperatures.

- **All Electric City -** Our December 2014 paper; 'Powering Ahead: Fast Track To An All-Electric City', making the switch to electric would not only generate a quieter city but would also improve air quality and reduce heat generation from building services and vehicles.

- **Green roofs** are vegetative layers grown on rooftops and were something heavily pushed in The New London Plan in 2007. There are a number of potential benefits from 'living roofs'; conserving and enhancing biodiversity, improving storm water attenuation and reducing the UHI effect. The latter is achieved by the shading of surfaces and increased evapotranspiration, both mechanisms for reducing ambient temperatures. Additionally, green roofs can act as an insulation barrier which can help to reduce overheating directly within a building.

- **Cool roofs and pavements** are made of highly reflective materials and reduce the absorption of solar energy. Studies on the use of 'white roofs' in the US show them to typically be 28 to 36°C cooler than dark roofs in afternoon sunshine. There are also suggestions that they can cool the top floor of a non-air conditioned building by 1 to 2°C. Equally, in mechanically cooled buildings a reduction for its demand can result in energy savings. Therefore not only would this help to reduce the UHI in cities, but would directly reduce the overheating risk of top floor flats and other rooms utilising roof space.

- **Increased shading from plants/trees** and increasing the amount of greenery would also help to cool urban areas. Trees reduce the amount of radiation that can reach below the canopy area, and increasing the amount of plants, shrubs and grasses enhances the rate of evapotranspiration. In the London plan, The Mayor had planned to have 10,000 trees planted by March 2012, with an additional 2 million by 2025. As of 2015, 20,000 have so far been planted.



Land Surface Temperature in London at 21:00 on 12 July 2006 (LUCID project)

Education/Behaviour

Simple measures such as when to have the blinds drawn to limit solar gain, and knowing the best times to open and close the windows can influence the temperature. There are also methods that reduce the internal gains such as switching to low energy lighting and by ensuring that all lights and electronic equipment are switched off when not in use. **Retrofitted LED lighting** may be beneficial as it would reduce the amount of heating gained from lights, owing to their greater efficiency. Improving public awareness of these simple measures may be the first step in eliminating unnecessary overheating.

5

WHAT ARE THE NEXT STEPS?

1. A ROBUST REGULATORY OVERHEATING ANALYSIS METHOD

First and foremost, changes need to be made to the way the issue is regulated; a robust, accepted overheating assessment needs to become a regulatory requirement in all new developments. As it stands, the current overheating check is not effective.

The type of assessment in question also needs to be considered. TM52 thermal dynamic modelling is currently available to assess the likelihood of a new building to overheat, but it is not mandatory. Developments in London must adhere to these standards, but its use is limited outside of the city. TM52 may not be the most appropriate method, but a similar standardised assessment tool should be introduced. Dynamic modelling is not without its limitations and there are possible alterations which could greatly improve the effectiveness and reliability of this type of analysis. The biggest problem is that the process is reliant on the input of assumptions, most of which are determined by the individual running the programme. These include:

- The time of day that living spaces are occupied.
- The temperature at which occupants will partially, and then fully open windows.
- The amount of time that windows are left open during the day.
- Internal gains created by occupants, appliances etc.

We recommend that a toolkit should be created to be used in coordination with the chosen standardised method of analysis (based on research), stipulating the assumptions that should be make for a number of given scenarios. The assessment could then only be passed using these assumptions. If for whatever reason these set values had to be altered, it would have to be made very clear in the results and would require adequate justification.

As it stands, developments in London also have to show compliance with TM49, which provides more extreme weather files; the prolonged period of warmth in 1979 and the intense two week heatwave in 2003. Beyond London, developments do not have to model to any of these warmer scenarios, the likes of which would be expected to become more prevalent under conditions of climate change. Whilst weather extremes tend to be exaggerated in London, these events are not exclusive to the capital. Therefore we feel that it is necessary for all new homes to model against an agreed weather file which incorporates the risk of a hotter climate. This would help to ascertain their level of preparedness for predicted future conditions, enabling developments to be future ready

2. ALL NEW HOUSING DEVELOPMENTS TO ADHERE TO A 'COOLING HIERARCHY'

The cooling hierarchy is again something advised by the Greater London Authority, but not generally followed elsewhere. Its use would aim to promote the use of passive measures as a method of reducing overheating risk in the first instance. If this could be justified as being unsuitable or unsuccessful in reducing overheating, then more energy intensive solutions could be considered. The process would demonstrate that cooling may not be necessary in all scenarios and cheaper, more efficient options may viable.

- **Cooling Hierarchy**
- **Passive Design:** Limiting solar gains by changing orientation, glazing and shading.
- **Passive/Natural Cooling:** Consideration for the availability of window opening as the primary method for ventilating the property.
- **Mechanical Ventilation:** To increase airflow
- **Cooling system:** Cooling to be used if all other methods are inappropriate, or unable to eliminate the need.

3. ALL NEW BUILDINGS TO BE DESIGNED TO FACILITATE RETROFITTED COOLING INSTALLATION:

As our research has shown, many homes will struggle to avoid overheating with passive measures alone, when tested against future scenarios. Therefore it is likely that more buildings will require mechanical cooling in the future. If new developments are already prepared to facilitate a cooling mechanism, this will make retrofitting easier, more efficient and cheaper and should also help maintain the aesthetics of the building. For example, new developments could have:

- A power supply that is sufficient to cope with the increase in energy demand resultant from the installation of mechanical cooling.
- A discreet area on the outside of the building for an outdoor unit.

4. A NUMBER OF MEASURES SHOULD BE INTRODUCED ON NEW DEVELOPMENTS TO REDUCE THE URBAN HEAT ISLAND

As discussed, increasing the type and prevalence of urban green space could make a big difference to city temperatures and be a successful strategy in tackling the overheating problem. Whilst the current mechanisms being used to facilitate the growth of green infrastructure are a step in the right direction, more can and should be being done.

Examples of measures include:

Development Scale

- **Green Infrastructure**
  There is a need for stronger planning policy and government initiatives to encourage the inclusion of green infrastructure in new projects. Incentive strategies, such as those used in Tokyo may be beneficial, where green roofs are compulsory for larger developments, alternatively, low interest loans and tax reductions could be offered to projects which voluntarily incorporate green infrastructure. This could not only be introduced on new developments, but retrofitted onto existing buildings. Green roofs have been shown to have a greater life span, improve air quality and reduce energy consumption of buildings . This information needs to be clearly communicated to developers to encourage the growth of green infrastructure, helping to turn policy into practice.

Neighbourhood Scale

There are a number of neighbourhood scale changes available which could be put under the control of local councils and implemented through such platforms as urban design strategy and local development framework. Interventions that may be effective include:

- **Cool Pavements**
  A gradual programme of replacing current paving with material characterised by high solar reflectivity and good water permeability could make a big difference to city temperatures.

- **Planting**
  Effective planting can reduce heat gain at ground level and evapotranspiration provides cooling.

- **Urban planning**
  Greater consideration needs to be undertaken with respect to the layout of new developments. The availability of air travel through a city can make a big difference to the local temperatures. Buildings located within street canyons would be likely to experience much lower temperatures and greater rates of air flow. The location and size of parks is also very important when it comes to spatial distribution of temperature.

5. THE “ALL-ELECTRIC CITY” SHOULD BECOME A POLICY PRIORITY

Electrification of all heating and vehicles in cities will be beneficial in lowering temperatures in built up areas. As well as the reduction in direct heat production from vehicles and buildings it will also improve air quality and levels of noise pollution which would increase opportunities for natural ventilation.

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