Summertime overheating in dwellings in temperate climates

BRIEFING NOTE

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ABSTRACT

Summertime overheating in both new and existing dwellings is widespread and increasing, even in temperate climates. There is an urgent need to solve the problem. Flats (apartments) and small dwellings, especially those in cities, are particularly at risk. Elderly and vulnerable people are particularly affected. This briefing note presents current knowledge about this problem and what might be done about it. It is directed at planners, designers, policymakers as well as local authorities, housing associations and other organisations that manage stocks of dwellings.

KEY FINDINGS

- The research community and others have revealed the extent, severity and causes of summertime overheating in dwellings.
- Flats, even in temperate climates, are particularly at risk of overheating. Methods of construction and refurbishment and global warming are making the problem worse.
- Overheating affects mortality and morbidity, with the elderly and vulnerable particularly affected.
- Well-established passive heat-protection measures can, in most cases, prevent or remove the problem.
- Examples of good design practice are being verified through monitoring and occupant experience surveys.
- Professionals concerned with the design and refurbishment of dwellings must now focus on keeping them cool in summer as well as warm in winter.

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1. PROBLEM DEFINITION

Widespread and severe summertime overheating of homes in temperate climates is a relatively new but urgent phenomenon. Heat-related illness and death due to high indoor temperatures is increasing. The 2003 heatwave accounted for over 30,000 deaths in Europe (Kosatsky 2005). The problem has been identified in many countries in both new and existing dwellings. Socially deprived households are often disproportionately affected. Governments and the house building and refurbishment industries have been slow to react, but action is now being taken.

Climatic warming and more frequent and severe heatwaves are important factors. New and existing flats (apartments), which are smaller, high rise, in city centres and without adequate heat protection, are especially prone to overheating. The problem is multifaceted, but can be mitigated, without recourse to air-conditioning, by thoughtful design and retrofit.

This briefing note explains the background to the problem, how overheating is defined, and the known effects of dwelling design and refurbishment. The crucial importance of dwelling occupants, the effects of overheating on them and their role in mitigating high temperatures is discussed. The difficulties of predicting the risk of overheating and of measuring its occurrence are explained.

2. CONTEXT

In Europe, over 36 million people live in high-rise tower blocks (IEA 2006). They are cost and space efficient and tend to be more energy efficient than other dwelling forms, but are also significantly more likely to overheat in summer (Lomas *et al.* 2021). The health of elderly and vulnerable citizens is particularly affected by summertime heatwaves (ONS 2019).

As the climate warms, and as cities become larger and denser, the prevalence of overheating is increasing. Overheating in dwellings has been reported in many countries with temperate climates, *e.g.* the UK, the US, New Zealand, Germany and France (Lomas & Porritt 2017). As with other elements of our built infrastructure, an urgent need exists to change the way that society designs, builds, refurbishes and operates homes in order to adapt to the warmer future.

European countries use different criteria to define overheating (BPIE 2015). The outcomes of analyses are very sensitive to the criterion chosen. In the UK, if bedrooms have > 1% of annual occupied hours at > 26°C, they are deemed to be overheated. For living rooms, a threshold temperature, which depends on outdoor temperature, is defined, and if > 3% of the occupied hours between May and September exceed this threshold, the space is deemed to be overheated (CIBSE 2017).

Mandatory regulations on overheating in new dwellings are proposed for the UK. Dynamic thermal models can be used to predict the likelihood of overheating in new buildings (CIBSE 2017). Measurements and inspections can be used to identify overheating in existing dwellings (ODPM 2006).

3. CURRENT STATUS

The worldwide research community has used models and full-scale experiments to understand the relationship between overheating and changes in the climate, dwelling design and occupant behaviour. Monitoring studies involving a few homes have identified specific features that lead to an increased risk of overheating (Lomas & Porritt 2017). The focus has been on comfort in living rooms and bedrooms so that sleep is not disrupted, which can be particularly debilitating.

Large-scale field trials have quantified the prevalence of overheating in existing housing stocks. Both the physical form of buildings *and* the way people occupy them are important, so a transdisciplinary perspective is essential. Clearly, the weather during such field trials affects the extent and severity of overheating: in the summer of 2010, 2% of living rooms in English homes (0.6 million) overheated, whereas in 2018, England's hottest summer, on record, the prevalence was 15%, *i.e.* 3.6 million (Lomas *et al.* 2021). However, field trials by different researchers and

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in different countries have provided a reasonably consistent picture of the correlation between overheating and the characteristics of dwellings and their occupants. Flats and other small dwellings, households in social housing with low income, and the elderly and vulnerable are especially at risk.

The drive to reduce construction cost, time and complexity creates a real risk that flats will suffer from chronic overheating (McLeod & Swainson 2016). The construction industry is beginning to recognise this, perceiving reputational damage as the public becomes increasingly aware of the problem. Property owners with a duty of care for their tenants are also concerned. In the UK, the Housing Health and Safety Rating System (ODPM 2006) includes guidance on identifying homes likely to overheat and the route to legal redress.

Refurbishment and remodelling can be a solution to overheating but it is often part of the problem (Baborska-Naroży *et al.* 2017). Buildings are subdivided, adequate ventilation prevented and lightweight top-lights and casement windows replaced by heavier, larger, restrictive and less flexible window solutions.

Appropriate design and passive heat-control measures can enable flats in temperate climates to be comfortable in summer. This avoids the use of air-conditioning, which can exacerbate climate change and increase a household's fuel bills.

4. KEY CONSIDERATIONS

Flats, both existing and new build, are significantly more likely to overheat than other dwelling types. Why is this, who is affected by it and what might be done?

4.1 WHY DO FLATS OVERHEAT?

Generic factors that lead to overheating can be readily identified; flats are often smaller than other dwellings, more densely occupied and have a reduced external surface area through which ventilation can be provided. On higher floors windows are less shaded by surrounding urban features, and top-floor flats are exposed to the sun-heated roof above. In addition to these solar gains, internal heat gains arise from the activities of the flat's occupants and from surrounding flats and common circulation areas. The hot air created on lower floors rises, making overheating on the higher floors even more likely.

Cities pose particular problems. The urban heat island can elevate night-time temperature 5–10 K above the surroundings, thus it reduces the benefits of night-time ventilation cooling. Land prices in cities are high and so are construction costs, so the pressure to reduce construction time and complexity is acute. Off-site construction is seen as one way to reduce costs, but in its extreme form, the stacked, flat-faced boxes can suffer from chronic and extreme overheating (Quigley & Lomas 2018).

In addition to the generic factors, design is important. Flats are often single aspect and relatively deep plan. In this situation, only single-sided ventilation is possible, which is much less effective than cross-ventilation. Flats may have large glazed areas to help 'off-set' the gloom of deep plan designs, but when facing towards the south and west these exacerbate overheating risks. Whilst external shading reduces solar heat gain, it also adds construction cost and complexity. 'Business-as-usual' windows and patio doors can be difficult for some people to operate, and security, pollution and noise concerns may deter their use. On higher floors window opening may be deliberately limited to roughly 100 mm on safety grounds. Hot water, piped from a central, communal heating plant, can be a permanent source of uncontrolled heat, and poorly designed and installed mechanical ventilation systems can actually contribute to overheating (McLeod & Swainson 2016).

It is not only new flats that overheat. Monitoring revealed that the living rooms in 30% of all English flats overheated in the summer of 2018 compared with 12% for all other dwelling types (Lomas *et al.* 2021). Retrofit can alleviate problems, but poorly conceived remodelling might turn a habitable apartment building into one with flats that overheat (Baborska-Naroży *et al.* 2017).

4.2 ENERGY EFFICIENCY AND OVERHEATING

It is frequently suggested that increasing the insulation levels of homes exacerbates overheating. However, some reporters mistake correlation for causation. Field studies have shown that there was no significant difference in the incidence of overheating with the presence, or otherwise, of cavity wall or loft or other insulation measures. Whilst dwellings with a good energy efficiency rating overheated significantly more than less efficient homes, this could be because they were also significantly more likely to be flats (Lomas *et al.* 2021). Modelling has shown that loft and external wall insulation can actually reduce both overheating and heating energy demand (Porritt *et al.* 2012). Both field studies (Tink *et al.* 2018) and modelling (Porritt *et al.* 2012) indicate that internal wall insulation may increase overheating risk, but simple passive measures can easily control this. In summary, it seems that energy efficiency measures to reduce energy demands and mitigate climate change are not in conflict with climate change adaptation.

4.3 WHO IS AFFECTED?

In households with elderly members the prevalence of overheating is significantly greater than in other households, and yet the reporting of overheating can be significantly less (Lomas *et al.* 2021). Combine the poor perception of heat by older people with their inherently poor thermoregulatory system, their greater physical and cognitive difficulty in operating windows and blinds, and their tendency to stay at home and so be exposed to the higher midday temperatures, then the high vulnerability of the elderly becomes apparent.

Flats (apartments) are a particular concern, not only for the elderly, because there is simply nowhere to go to escape the heat. Some flats may have small balconies, but the shade and cool breeze found in the private gardens and yards of low-rise dwellings are unavailable. Since homes need to be safe and healthy for all citizens, the needs of the elderly should drive building design and refurbishment thinking.

4.4 PREVENTING OVERHEATING

Avoiding overheating involves several design considerations: limiting the scale of the problem; providing passive cooling measures; and empowering occupants.

Steps to reduce overheating risk need to consider both the building and its setting. Planning might produce quiet shaded courtyards, with buildings that mutually shade each other, introduce light-coloured surfaces, and planting and water features to reduce urban heat (***Figures 1*** and ***2***).

Designers might produce plan forms that can be cross-ventilated, with carefully articulated glazing and attention to glazed areas on sun-facing facades. The provision of shaded balconies or other communal spaces where people can escape from heat should be seriously considered. Engineers should give early thought to the provision of hot water and ventilation to curb heat build-up. Domestic mechanical ventilation systems provide too little air for effective ventilation cooling and systems with heat recovery need to have a functioning summertime bypass and avoid heat 'pick-up' from hot water piping and other sources. Corridors should also be adequately ventilated; they are often a route for hot water pipes.

Passive control of solar gain is effectively achieved through external shading, *e.g.* through facade articulation, overhangs and side fins. External shutters, sliding panels and movable blinds are also effective. Low *g*-value glass can supplement these strategies. Internal shading is much less effective, but helpful. Passive ventilation is most frequently provided by windows and perhaps doors, but the dwelling must remain secure. Noise and security concerns may make simple, conventional solutions less effective. Tried and tested, but rarely used, strategies, such as louvered side panels, acoustically attenuating window systems and off-standing secondary facades, might become more common place (***Figures 1*** and ***2***). Such strategies should enable night ventilation that can effectively cool spaces, especially if thermally massive construction is used.

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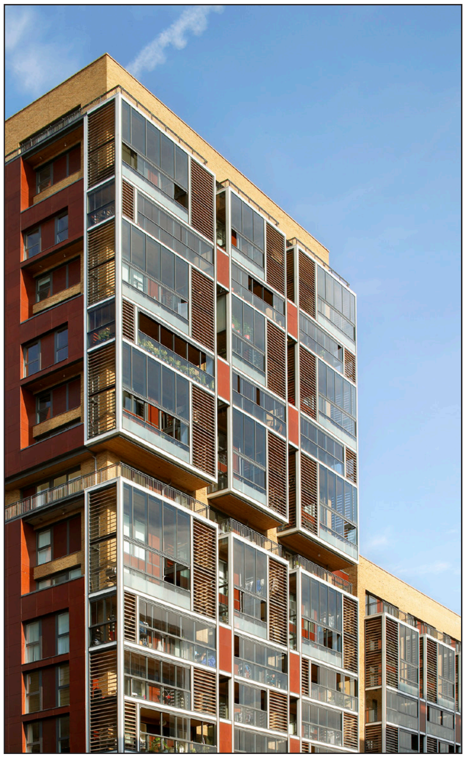

Figure 1 (left): Mitigating overheating risk with noise-attenuating sunspaces.

Note: On this west-facing facade, offstanding glazed sunspaces provide protection from noise and reduce solar gain while preserving daylight and views. Louvered panels provide ample permanent ventilation preventing the sunspaces from overheating.

Source: Arup.

Figure 2 (right): Mitigating overheating risk with shaded balconies.

Note: East-facing, single-aspect flats with large areas of glazing are shaded by the balcony above and the roof overhang. Side-fins shade out the sun in the south, creating an egg-crate facade design. The resulting large balconies provide safe, external space. Pale colours help reduce surface temperatures. The creation of a quieter, vehicle-free plaza with planting reduces noise and pollution.

Architect: John McAslan + Partners. Photo: Joe Clark (*http://joeclark.photo/*).

People need to be empowered so they can operate ventilation and shading systems effectively. Intuitive, accessible and useable devices, with advice on how to use them, are needed. Thinking about elderly people will help get this right. Handles need to be robust, within reach (both when closed and open) and simple to operate, and avoid complicated/difficult locks and keys and heavy doors. Openings of different size offer flexibility. Currently, whether in new or existing dwellings, these matters are given little, if any, thought. A homeowners' manual can help enormously by providing advice and illustrations on how and when to operate shading and ventilation devices. Simple advice, *e.g.* when to shade and ventilate bedrooms and how to cross-ventilate might, quite literally, be a lifesaver. Temperature monitoring, perhaps using smart home technology, could help protect the elderly, ill and disabled by alerting them and their carers to impending elevated temperatures (Gustin *et al.* 2020).

Guidelines and standards are emerging that cover all aspects of overheating design, from initial concept through to detailed engineering. These are listed in the Further Reading section below. Guidance on effective refurbishment and remodelling is currently limited.

5. CONCLUSIONS

The extent and severity of summertime overheating in temperate climates is reasonably well known. Whilst there remains useful work to be done, the main challenge is to effect change within governments and the planning, construction and engineering sectors.

Flats (apartments) are especially at risk of overheating because ventilation is constrained, glazing areas can be high, and there is often high and uncontrolled heat gain. In cities, noise, security, safety, pollution and the urban heat island exacerbate the problem.

Policies and practices to improve energy efficiency in winter, do not *per se* precipitate increased summertime overheating. Rather, it is the lack of passive cooling provision, especially adequate shading and ventilation, that is the problem.

Society's most vulnerable are particularly at risk from summertime overheating, especially those who are old, with disabilities, ill, have low incomes or are living in rented accommodation. Homeowners' guides, and temperature monitoring using smart home technology, could provide them with protection during hot summers.

There are an increasing number of design guidelines and tools to assist in producing new flats that are comfortable in summer, but guidance on retrofit and remodelling is scarce.

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6. RECOMMENDED ACTIONS

In several countries with temperate climates, there are guidelines and recommendations on allowable summertime temperatures. However, as summertime overheating becomes more prevalent, there is an urgent case for robust, mandatory heat-protection regulation. Building Regulations applicable to all new dwellings in England and Wales are planned. In future, regulations and supporting guidance aimed at existing housing stocks in temperate climates may be needed to ensure that retrofit improves heat resilience.

The technology to monitor temperatures in homes is low cost, but an agreed monitoring protocol and a method for interpreting the measurements are needed to establish definitively whether or not a space is overheated.

An approved measurement procedure would provide a route by which households, property owners, care workers, *etc.* could determine if a dwelling overheats and thus seek redress to alleviate their plight. A method of enforcement and clarity over responsibility for summertime comfort could then be established. Governments could readily measure the efficacy of policies to reduce overheating.

Dynamic thermal models can be unreliable predictors of overheating risk (*e.g.* Roberts *et al.* 2019). There remains a need for advice and guidance about precisely how to model and interpret the results. This is a matter for joint academic and industry research.

New dwellings could have a service life of 60–150 years, so designers must anticipate future climatic conditions and changes such as increased daytime occupancy and home working. Looking forward just three or four decades, it is very likely that overheating will be unavoidable in some dwellings in some locations, even in temperate climates. Although people adapt, safe havens or 'cool rooms' might be required. The provision of these without resorting to whole house air-conditioning would be the challenge.

Finally, passive control of overheating relies heavily on the appropriate actions of people, and increasingly in the developed world, older people. Homeowners' manuals that provide guidance to inhabitants on 'staying cool in summer' should be supplied by building owners or building managers acting on their behalf.

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COMPETING INTERESTS

The author has no competing interests to declare.

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FURTHER READING

This list provides a few key sources, which also direct the reader to other material covering specific topics in more detail.

ANC & IoA. (2020). *Acoustics, ventilation and overheating, residential design guide*. Acoustics and Noise Consultants (ANC) and Institute of Acoustics (IoA). *https://www.association-of-noise-consultants.co.uk/wp-content/uploads/2020/07/ANC-AVO-Residential-Design-Guide-January-2020-v1.1.pdf*
This guide from the ANC and IoA provides advice, supported by detailed analytical methods, to enable design and retrofit that enables the passive control of overheating, whilst limiting the effects of noise. The ANC's website has much other information about noise and overheating, including examples of noise-attenuating glazing and ventilation systems. *https://www.apexacoustics.co.uk/noise-ventilation-and-overheating-in-dwellings/*.

CIBSE. (2013). *Limits of thermal comfort: Avoiding overheating in European buildings* (Technical Memorandum No. TM52). Chartered Institution of Building Services Engineers (CIBSE). *https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I7f5AAC*
Applicable across Europe, this guide explains the principles behind adaptive thermal comfort and presents the consequential overheating criteria now used to underpin many subsequent guidelines and standards. It provides essential but compact reading on the topic. The design of flats, and their assessment using dynamic thermal models and criteria given in TM52, is described in Technical Memorandum No. 59, which is referenced below (CIBSE 2017).

CIBSE. (2018). *Good practice in the design of homes* (Technical Memorandum No. TM60). Chartered Institution of Building Services Engineers (CIBSE). Chartered Institution of Building Services Engineers (CIBSE). *https://www.cibse.org/knowledge/knowledge-items/detail?id=a0q0O00000Di83DQAR#:~:text=For%20the%20purposes%20of%20this,easy%20to%20operate%20and%20maintain*
The principles of designing new dwellings to avoid overheating is outlined in section 5.6 (pp. 18–22), with table 3 (p. 21) providing a useful checklist of the common causes of overheating and mitigation measures.

GHA. (2019). *Overheating in new homes tool and guidance for identifying and mitigating early stage overheating risks in new homes*. Good Homes Alliance (GHA). *https://goodhomes.org.uk/wp-content/uploads/2019/07/GHA-Overheating-in-New-Homes-Tool-and-Guidance.pdf*
Focused specifically on the early-stage design of new dwellings in the UK, this guide contains advice and images on design to avoid and mitigate overheating. An early-stage overheating risk tool provides a scoring system by which to determine if a new dwelling is likely to overheat. The tools indicate that dwellings in the South East of England, where window opening is curtailed and glazing areas are large, have a high risk of overheating.

Mayor of London. (2018). *Energy, overheating and daylight in tall buildings study* (Local Plan Supporting Study). Old Oak and Park Royal Development Corporation, Buro Happold, for the Mayor of London. *https://www.london.gov.uk/sites/default/files/16._energy_overheating_and_daylight_in_tall_buildings_study_2018.pdf*
Dwellings and flats in London are especially at risk of overheating, and so the Mayor of London has established planning requirements that require large developments to be assessed for overheating risk. This document seeks to understand the viability and technical feasibility of meeting and surpassing the draft new London Plan aspirational targets for passive energy performance in tall developments. It illustrates which tall buildings are at risk and the measures that can be used to mitigate overheating.

Passivhaus Trust. (2016). *Designing for summer comfort in the UK: Revision 0.1*. The UK Passive House Organisation.
Concern about overheating in summer is heightened, correctly or not, in dwellings with high levels of insulation. This guide provides advice focused specifically on Passive Houses. Appendix 2 provides a useful checklist of risks, remedial actions and if specialist advice is needed. Considerably more information is provided from the Passive House Institute website via the Passivhaus Planning Package. *https://passivehouse.com/04_phpp/04_phpp.htm*

ZCH. (2016). *Solutions to overheating in homes: Evidence review* (March). Zero-Carbon Hub (ZCH). *https://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCH-OverheatingEvidenceReview.pdf*
Contains a thorough treatment of measures to mitigate overheating in new dwellings and refurbishments. Covers all aspects from the design of the urban realm, through dwelling form and fabric, to details of glazing, ventilation and building services. Other documents produced by the ZCH cover various aspects of the problem.

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