**Institution:** Loughborough University

**Unit of Assessment:** C13 Architecture, Built Environment and Planning

**Title of case study:** Reducing summertime overheating in buildings to assure health and wellbeing and protect life

**Period when the underpinning research was undertaken: 2012 – present**

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s): | Role(s) (e.g. job title): | Period(s) employed by HEI: |
|---|---|---|
| Kevin Lomas | Professor | 13.10.08 - present |
| David Allinson | Senior Lecturer | 1.6.2009 - present |
| Robert McLeod | Senior Lecturer | 14.12.16 - 21.9.19 |

**Period when the claimed impact occurred: 2014 - 2020**

**Is this case study continued from a case study submitted in 2014?** No

## 1. Summary of the impact (indicative maximum 100 words)

The frequency of heatwaves is increasing, and heat-related deaths in the UK are expected to triple by the 2050s. Research at Loughborough University (LU) produced the first quantified evidence of the extent and severity of summertime overheating in English homes and hospitals. Extensive public engagement and lobbying created pathways to the following chain of impacts: 1) compelled UK government to take action to tackle overheating; 2) shaped government policy on overheating in existing English homes; 3) new building industry guidelines and standards to predict the risk of overheating in new homes; 4) new Building Regulations to mitigate overheating in all new homes in England and Wales.

## 2. Underpinning research (indicative maximum 500 words)

Beginning in 2008, research at LU has quantified the severity and extent of summertime overheating in homes and hospitals, identified the buildings and people most at risk, and described how policy and practice should change to mitigate the problem. The research team has been led by *Lomas,* with *Allinson* and *McLeod,* and contributions from *Beizaee, Firth, Hopfe, Loveday* and *Porritt,* supported by six Research Associates.

**Large-scale field trials** yielded three primary data sets to determine the extent and severity of overheating and enable the creation of new empirical models. Before 2017, these were the only large-scale surveys of summertime overheating in UK buildings.

In the CARB project, a dwelling survey, face-to-face questionnaires and temperature monitoring were conducted in 252 homes distributed across England. This was the first national survey of summertime temperatures and output [R1] is the first publication to reveal, through measurement, the extent and severity of overheating in English homes.

A more focussed study, the 4M project, gathered in-depth data on temperatures, energy use, and household composition from 230 homes in the city of Leicester. The study identified continued space heating during the summer as a contributor to overheating [R2].

Concern about overheating in hospitals, led to the DeDeRHECC project, in which temperatures were monitored in 125 hospital wards in nine NHS buildings in Cambridge, Bradford, Leicester, and St. Albans. The research demonstrated that hospital wards across the country, which should provide a safe-haven during heat waves, would themselves overheat in hot weather. It also revealed the weakness of the prevailing thermal comfort standards and the need for robust regulatory control of overheating [R3]. It remains, to the researchers' knowledge, the only large-scale study of temperatures in hospital wards.

The Government's most detailed England-wide survey of summertime overheating since 2011 was commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) who funded *Lomas* and *Allinson* to analyse data from the 2017 Energy Follow-up Survey (EFUS) to the English Housing Survey.

**Full-scale experiments** have been undertaken in two sets of matched-pair homes with simulated occupancy. These unique LU facilities have quantified the impact of thermal mass, ventilation, and shading on summertime overheating risk [R4].

**Case-studies** of occupied dwellings**,** including super insulated homes to Passivhaus standards, have enabled forensic investigation of the mechanisms causing overheating. The phenomenon of chronic overheating in new-build flats was identified [R5].

**Dynamic thermal simulation** enabled the evaluation of overheating risk in proposed hospitals and homes in both current and future climates [R4]. Validation of others' predictions was undertaken to test the suitability of dynamic thermal modelling for overheating risk assessment within new Building Regulations for England [R6].

As recognised leaders in the field, *Lomas* and *Porritt* were invited to edit a special issue of Building Research and Information (BRI) on overheating [R7]. The editorial's new insights have provided a platform for the research of others. R7 is the most cited BRI editorial ever.

**3. References to the research** (indicative maximum of six references)

Since 2012, a substantial body of work about summertime overheating in homes and hospitals has been authored, including: 24 refereed articles and 20 conference papers.

**R1**. Beizaee A, Lomas KJ and Firth SK (2013) *National survey of summertime temperatures and overheating risk in English homes*, Building and Environment, 65, pp1-17. DOI: 10.1016/j.buildenv.2013.03.011

**R2**. Lomas KJ and Kane T (2013) *Summertime temperatures and thermal comfort in UK homes,* Building Res. and Inf., 41, 3, pp259-280. DOI: 10.1080/09613218.2013.757886

**R3**. Lomas KJ, Giridharan R (2012) *Thermal comfort standards, measured internal temperatures and thermal resilience to climate change of free-running buildings: a case-study of hospital wards*, Build. & Env., 55, 57-72. DOI: 10.1016/j.buildenv.2011.12.006

**R4.** Tink V, Porritt S, Allinson D, Loveday D (2018) *Measuring and mitigating overheating risk in solid wall dwellings retrofitted with internal wall insulation,* Build. & Env., 141, pp247-261. DOI: 10.1016/j.buildenv.2018.05.062

**R5**. McLeod RS and Swainson M (2017) *Chronic overheating in low carbon urban developments in a temperate climate,* Renewable and Sustainable Energy Reviews, 74, 201-220. DOI: 10.1016/j.rser.2016.09.106

**R6**. Roberts BM, Allinson D, Diamond S, Abel B, Bhaumik CD, Khatami N and Lomas KJ (2019) *Predictions of summertime overheating: Comparison of dynamic thermal models and measurements in synthetically occupied test houses.* Building Services Engineering Research & Technology, Vol 40, pp 512-552 (2019). DOI: 10.1177/0143624419847349

**R7**. Lomas KJ and Porritt SM (2017) *Overheating in buildings: lessons from research.* Special Issue, Overheating in Buildings: Adaptation Responses, Building Research & Information, 45, Issues 1&2, pp1-18. DOI: 10.1080/09613218.2017.1256136

R6 won the Chartered Institution of Building Services Engineers (CIBSE) Carter Bronze Medal for the best application paper in 2020. The research was supported by three competitively-awarded EPSRC research grants valued at over £6.5M; DeDeRHECC (CI *Lomas*), 4M (PI *Lomas*, CI *Allinson*) and CARB (PI *Lomas*, CI *Firth*), which received the most funding in its funding call. Subsequently, BEIS funded *Lomas* and *Allinson* to undertake the overheating analysis for the 2017 EFUS.

**4. Details of the impact** (indicative maximum 750 words)

Since July 2014, because of the national concern about overheating [S1], the visibility of the Loughborough team's research has been amplified to public and building professional audiences. **Pathways to the impacts** described below have comprised:

a) seven invited media interviews (e.g., BBC News, ITV News, BBC Radio 4); newspaper articles (e.g., *Daily Telegraph*, *Financial Times*); six widely circulated professional press reports (e.g., *CIBSE Journal*, front cover article, the *Royal Institute of British Architects Journal*); and the worldwide reporting of R7 in specialist and general media outlets [S2].

b) a debate organised by The Edge, a campaigning, multi-disciplinary, built environment think-tank. *Lomas,* the lead speaker, addressed influential stakeholders from policy, architecture, house building, health, etc. including Lynne Sullivan OBE, Chair of the Good Homes Alliance (GHA); Alan Penn, Chief Scientific Advisor to the Ministry for Housing Communities and Local Government (MHCLG); Angie Bone, Head of Extreme Events and Health Protection at Public Health England; and Julie Godefroy, Technical Manager, CIBSE. The '*Edge Debate was lively, powerful and influential'* and '*led directly to action*' [S3] by the GHA and CIBSE (see Impact 3).

c) presentations at industry conferences and exhibitions [S2]. Following his 2017 Eco-Build talk, delivered from the stand of the Building Research Establishment (BRE), *Lomas*

was invited to provide input to the second National [climate change] Adaptation Programme and to the research steering group of the project exploring changes to the building regulations. A presentation at the 2017 CIBSE Symposium [S2] led to research [R6] to evaluate the reliability of dynamic simulation models (DSMs) for overheating prediction within new Building Regulations (see Impact 4).

The team's research, and the above activities, initiated a **chain of impacts**. Each impact makes an important contribution towards reducing overheating in buildings and provides an essential link in the chain which led to new Building Regulations for dwellings in England and Wales.

**1. Compelled Government to address overheating in buildings:** The UK Government took action to curb summertime overheating in UK buildings as a direct result of LU research which revealed, for the first time, the severity and extent of overheating in English homes and hospitals. The research evidence was delivered to government via the reports of the Adaptation Sub-Committee of the Committee on Climate Change (ASC), the Zero-Carbon Hub (ZCH) and other organisations. The ASC was established following the Climate Change Act, to assess the risks arising from climate change. The Government is compelled by law to heed the advice and guidance of the ASC and report back on the actions taken.

The ASC first alerted the UK Government to the problem of overheating in its 2014 report which relied almost exclusively on the large-scale field trials undertaken by LU, there being no other empirical evidence, at scale, available at the time [S4]. Referring to output [R1], the ASC noted that '*Few studies have tried to monitor temperatures in homes across the country. One study …. found that 21% of homes studied exceeded overheating thresholds….*' [S4]. Based on the work in the DeDeRHECC project, the ASC also reported that '*Overheating is also a potentially serious issue in hospitals, …*' [S4].

In 2017, LU research was used by the ASC to further reinforce its evidence base and reiterated its call for government action. The report cited nine journal articles authored by LU staff, including R1 and R2. Based on this evidence, the ASC classified '*risks to health, wellbeing and productivity from high temperatures'* in its highest climate change risk category and a priority area for government mitigation action [S4].

The LU research also spurred others into action, notably The Zero Carbon Hub (ZCH), which had operational responsibility for achieving the (then) government target of delivering zero carbon homes in England from 2016. The ZCH mission also encompassed the unintended consequences of high levels of insulation, which includes summertime overheating. The ZCH 2015 report, '*Overheating in Homes: The Big Picture'*, relied on [R1] and [R2] to evidence the extent of overheating [S4]. Subsequently, the ZCH published over 18 reports and other documents about the problem of overheating and led them to '*make recommendations to government and industry decision-makers on the types of frameworks which could cost-effectively incentivise …. action to tackle overheating in homes*.' [S4].

In 2018, the House of Commons Environmental Audit Committee asked the Government to explain its actions in response to the ASC's recommendations to protect homes and public buildings, improve the resilience to heat waves of health care provision, and to change the Building Regulations [S1]. In its response [S1], the Government said '… *MHCLG will consult on a method for reducing overheating risk in new homes*'. The Government's decision was a foundational link in the chain to Regulatory change reported as Impact 4.

**2. Shaped Government policy:** The research team was funded by BEIS, through the BRE, to undertake an analysis of overheating within the 2017 Energy Follow-up Survey (EFUS) [S5]. This was '*the largest survey of temperatures in English homes'*, [S6] with measurements being made in 750 homes during England's hottest ever summer. The EFUS '*provides the UK government with its primary source of data about the English Housing stock'* and enables BEIS '*to track the incidence of overheating … as the climate changes'* [S6]. Analysis methods developed through research were applied to data generated in an England-wide survey of temperatures in homes.

The EFUS reports were shared across Whitehall, and *Lomas* and colleagues reported their findings on four occasions to more than 15 government officials including John Saltmarsh, Deputy Director Engineering and Research at BEIS; Hunter Danskin, MBE, then Head of Technical Analysis at BEIS; and Victoria Tink, Building Regulations Part L Policy

Lead, Technical Policy Division, MHCLG. The insights will shape the Government's future policies on energy efficiency and overheating.

The monitoring campaign had four policy impacts. Firstly, the analysis '*represented a break from the 'time honoured' approach and .... proved much more insightful'.* In particular, '*it is now clear that householders' self-reporting cannot be used as the principal measurement of overheating in housing stocks'*, which has important implications for the conduct of future EFUSs [S6]. Secondly, the analysis was '*crucially important as it permits BEIS to advance policies to reduce greenhouse gas emissions through improved energy efficiency without necessarily increasing the risk of overheating*' [S6]. Thirdly, and more generally, the work has provided the platform for framing '*future policies to reduce the risk of overheating*' [S6]. Interestingly, and unexpectedly, the analysis approach has also enable BEIS '*to understand more about wintertime underheating*' and fuel poverty, identifying '*which dwellings, with which occupants, are most at risk of ill-health*' [S6].

**3. New building industry guidelines and standards:** To enable the design of homes that are free of overheating, LU research has contributed to the development of new guidelines and standards and train engineers to use them.

The GHA, a charity that '*promotes higher quality sustainable housing and standards amongst architects, designers and house providers',* drew on the early research of Porritt. In 2014 he sat on the GHA Working Group [S7] that led to the GHA report, *'Preventing Overheating: Investigating and reporting on the scale of overheating in England'.* In 2019, as a direct result of the Edge Debate (see above), the GHA developed new guidance and a toolkit to identify new homes at risk of overheating [S7], the only academic work referenced is [R1]. *Lomas* heralded this innovation in an invited article for Buildings and Cities, the article was accessed over 1000 times in the two months post-publishing [S7]. The guidelines and tool kit were downloaded 1200 times in the first nine months after publication [S7].

CIBSE Technical Memoranda (TMs) are the primary point of reference for engineers in the UK and overseas concerned with providing comfortable and healthy buildings. They are the de-facto design and modelling standards referred to in the Building Regulations. In 2016, *Lomas* was the only academic invited to join the peer-review panel that oversaw the development of two new CIBSE TMs concerned with overheating in dwellings: TM59, which prescribes how engineers should use DSMs to identify designs which are likely to overheat; and TM60 to provide guidance on reducing these risk [S7, S8]. In the first three years after publication, over 4,100 copies of TM59 were downloaded from the CIBSE website [S7].

In 2018, in association with Design Builder, who provide the user interface to the world's most widely used DSM, EnergyPlus, *McLeod* and *Hopfe* ran a CPD workshop to train consultants in the assessment of overheating risk using TM59 [S7].

Since December 2018, '*the designers of all new homes and developments in London are required to demonstrate compliance with TM59'* [S8]; design refinements are required if proposed dwellings fail to comply [S7].

**4. New Building Regulations in England and Wales:** LU academics demonstrated the uncertainty in the overheating predictions of DSMs and contributed to the Technical Working Group that formulated new Building Regulations.

In 2015, the CCC's Progress Report to Parliament called on the MHCLG to '*… introduce a new required standard or regulation on overheating for new homes.'* The call was repeated in 2018 by the Environmental Audit Committee (EAC) saying the government should '*create a regulation to stop buildings which are prone to overheating',* they suggested: '*make use of a dynamic thermo-modelling test, such as the Chartered Institution of Building Services Engineer's TM59 and TM52 guidance, a regulatory requirement for new buildings*' [S1]. The CCC and EAC reports '*galvanised activity at the MHCLG'* [S9].

However, much work was needed before such profound changes could be implemented and LU research was crucial: the MHCLG '*used a copy of*' our research [R7] '*in the office while undertaking the research and later during policy development*', *'to help explain to people across the Department and Government why action is needed'* [S9].

In 2017, *Lomas* was invited by DEFRA to join the research steering group for the project led by AECOM [S9, S10] to investigate trade-offs between the costs to the construction industry and the improvement in health and life expectancy that would result from regulatory

change. *Lomas* provided '*invaluable expertise'* [S9]. The project referred to four LU outputs including [R1 & R2] and concluded that regulatory change was desirable.

DSMs offer one possible approach to assessing the likelihood of overheating in new dwellings; but the reliability of their predictions is unknown. Working with industry partners, and with the encouragement of CIBSE [S8], the LU research team quantified the reliability of the most widely used DSMs when using the approach outlined in TM59 [R6]. The work was widely reported [S2] and demonstrated that DSMs produced surprisingly wide variations in predictions. The work helped to '*understand if and how dynamic thermal modelling might play a role in regulating overheating risk*' [S8].

In July 2019, the Building Regulations Advisory Committee, which is sponsored by the MHCLG, recruited new members whose work included overheating risk assessment [S10]. The Technical Working Group on overheating was set up by Tink (MHCLG, Building Regulations Part L Policy lead), '*to transform the body of research findings into a strategy for reducing overheating risk*' [S9]. Tink is a graduate of the London-Loughborough Centre for Doctoral Training (supervisor *Allinson*, see also [R4]), *McLeod* was also a member of this Working Group.

The Welsh and English governments have committed to mitigating overheating in new homes. Proposed new Building Regulations were published by the Welsh Government and the English Government [S10], with both governments creating entirely new Parts to the Regulations that focus solely on overheating. Both a simplified method, which draws on the GHA guidance, and a method based on the TM59standard and the use of DSMs, are presented. These new Regulations apply to all new homes in England and Wales and affect the whole housebuilding industry.

In [S9], Tink comments that LU research has '*broadened our understanding of the issues around overheating in homes, and the way that these insights have shaped the work of the MHCLG*'. The new Regulations '*…., will be, to my knowledge, the first time that requirements will be imposed on the design of new buildings, due to concerns for human health and well-being, as a direct result of climate change'.*

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

**S1. Policy Change:** Environmental Audit Committee action call & Government's response.
**S2. Alerting the Public and Professions:** TV and radio appearances, press articles, professional journal articles and talks at industry exhibition and symposium.
**S3. Impact of the Research and Edge debate:** Letter of Corroboration, Richard Lorch (Editor of Buildings and Cities and former editor of Building Research and Information).
**S4. Initiating Government Action:** Evidence of LU research initiating and sustaining pressure on the UK Government to act to curb overheating in UK homes and hospitals.
**S5. The National Overheating Survey:** The EFUS report on overheating.
**S6. Impact of the Overheating Analysis:** Letter of Corroboration, Hunter Danskin, OBE (Science and Innovation for Climate Change, BEIS).
**S7. New Toolkit, Guidance and Training:** Evidence of contributions to the Good Homes Alliance Toolkit and Guidance, to CIBSE TM59 and to Design Builder software training.
**S8. Modelling and Building Regulations:** Letter of Corroboration, Anastasia Mylona (Head of Research, CIBSE).
**S9. Regulatory Change:** Letter of Corroboration, Victoria Tink (MHCLG, Part L Policy lead).
**S10. New Regulations:** BRAC call for overheating expertise, Membership of MHCLG/DEFRA project Steering Group (for AECOM) and the proposed new Regulations.