Institution: University College London		
Unit of Assessment: 13 – Architecture, Built Environment and Planning		
Title of case study: Mitigating overheating in dwellings: providing research to support UK national policy to address climate-change risks associated with high temperatures		
Period when the underpinning research was undertaken: 2012-2015		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Michael Davies	Professor of Building Physics and Environment	2004-present
Anna Mavrogianni	Associate Professor in Sustainable Building and Urban Design	2008-present
Eleni Oikonomou	Senior Research Fellow	2010-present
Phil Symonds	Lecturer in Machine Learning for Smart Buildings and Cities	2014-present
Period when the claimed impact occurred: 2014-2019		
Is this case study continued from a case study submitted in 2014? N		

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

Research by The Bartlett into overheating in buildings has informed the UK government's position that risks to health, wellbeing and productivity from high temperatures is the second most important climate-change risk facing the country. This work has directly impacted national policy, with a section of the 2018 UK National Adaptation Programme (NAP) devoted to 'Overheating in buildings'. The NAP is pivotal in setting out actions that the government takes, and will take in future, to address risks posed by climate change – and research by The Bartlett has contributed to the recommendation for building regulations to address the risk of overheating in homes.

2. Underpinning research (indicative maximum 500 words)

Overheating was identified as a key climate change risk in the government's first UK Climate Change Risk Assessment in 2012. The Bartlett's Complex Built Environment Systems (CBES) group was part of the team commissioned by the Department of Communities and Local Government to carry out an evidence review of overheating in homes and conduct an analysis of gaps and recommendations (DCLG, 2012a and 2012b). The evidence review found substantial gaps in knowledge, concluding that significant research activity was required to improve the fundamental understanding of health effects and behavioural aspects of indoor overheating and building performance. When the second UK Climate Change Risk Assessment report was published in 2017, it cited CBES research, noting that, since 2012, "further evidence has been produced that considers the current and future risks from overheating".

Modelling heat and energy performance in buildings

The research has made important contributions to understanding the impacts of indoor overheating risks to public health and generating evidence of the approaches to mitigate them. This has been achieved through a combination of indoor thermal monitoring campaigns in homes and by developing housing stock indoor environment models. Modelling utilised a range of methods, such as physics-based dynamic building performance modelling, geographic information systems, artificial neural networks and microsimulation. This enabled CBES to take into account multiple factors of indoor heat risk, including climate, the urban heat island effect, building fabric, human behaviour, and social determinants of heat vulnerability. Resulting models are scalable and adaptable and can predict changes in excess indoor temperature exposure and its potential adverse impacts on health, for various scenarios of climate change, energy retrofit, and building-stock growth.

Key research outputs revealing overheating risks and mitigation pathways

Six key research outputs reveal overheating risks and mitigation pathways.

Modelling results for the UK housing stock indicated that weather influences the ranking of relative overheating risk by dwelling type **[a]**. It demonstrated that building characteristics and dwelling type have a greater influence on the variation of indoor summer temperatures than the location of a dwelling within London's Urban Heat Island **[b]**. This work was further developed in **[c]**, which found that London's spatial variation of heat-related mortality risk reflects background mortality rates due to population age. Some energy efficiency building fabric upgrades – such as internal wall and floor insulation – may increase indoor temperatures and, as a result, increase the risk of summer overheating in homes, if no appropriate measures (such as night time ventilation) are undertaken **[d]**. Modelling the future climate showed that natural ventilation strategies may reduce overheating risk to some extent, with night cooling and shading being slightly more effective than daytime ventilation.

Modelling building stock also highlighted the importance of dwelling type for indoor overheating and air quality ($PM_{2.5}$) **[e]**. Flats showed higher concentrations of internally generated indoor air pollutants and lower concentrations of outdoor pollutants infiltrating indoors; the inverse was observed for detached dwellings. This relationship was modified during warm periods by window opening, suggesting that as temperatures increase, occupants in passively-cooled homes are exposed to relatively higher levels of outdoor pollutants and face a potential trade-off between cooling and indoor air quality. The influence of dwelling type was corroborated through an indoor temperature monitoring study of social housing in which flats would overheat even during mildly warm weather **[f]**.

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

a) Taylor, J., Davies, M., Mavrogianni, A., Chalabi, Z., Biddulph, P., Oikonomou, E., Das, P. and Jones, B. (2014), The relative importance of input weather data for indoor overheating risk assessment in dwellings, *Building and Environment*, 76, 81-91. https://doi.org/10.1016/j.buildenv.2014.03.010

b) Oikonomou, E., Davies, M., Mavrogianni, A., Biddulph, P., Wilkinson, P. and Kolokotroni, M. (2012), Modelling the relative importance of the urban heat island and the thermal quality of dwellings for overheating in London, *Building and Environment*, 57, 223-238. https://doi.org/10.1016/j.buildenv.2012.04.002

c) Taylor, J., Wilkinson, P., Davies, M., Armstrong, B., Chalabi, Z., Mavrogianni, A., Symonds, P. and Oikonomou, E. (2015), Mapping the effects of Urban Heat Island, housing, and age on excess heat-related mortality in London, *Urban Climate*, 14, 517-528. https://doi.org/10.1016/j.uclim.2015.08.001

d) Mavrogianni, A., Wilkinson, P., Davies, M., Biddulph, P. and Oikonomou, E. (2012), Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings, *Building and Environment*, 55, 117-130. https://doi.org/10.1016/j.buildenv.2011.12.003

e) Taylor, J., Mavrogianni, A., Davies, M., Das, P., Shrubsole, C., Biddulph, P. and Oikonomou, E. (2015), Understanding and mitigating overheating and indoor PM2. 5 risks using coupled temperature and indoor air quality models. *Building Services Engineering Research and Technology*, 36(2), 275-289. https://doi.org/10.1177%2F0143624414566474

f) Mavrogianni, A., Taylor, J., Davies, M., Thoua, C. and Kolm-Murray, J. (2015), Urban social housing resilience to excess summer heat, *Building Research and Information*, 43(3), 316-333. https://doi.org/10.1080/09613218.2015.991515

Funding provided by the Engineering and Physical Sciences Research Council platform grants:

- Complex Built Environment Systems, 2006-2011 (GBP438,077)

- The Unintended Consequences of Decarbonising the Built Environment, 2011-2016 (GBP1,429,505)
- Built Environment Systems Thinking, 2017-2023 (GBP1,564,041)

The National Institute for Health Research Health Protection Research Unit:

- Air pollution and Weather-related health impacts: methodological study based on spatio-temporally disaggregated multi-pollutant models (AWESOME), 2011-2015 (GBP462,677)

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

The research has been instrumental in raising the profile within UK government of the risks to public health associated with overheating in buildings, and providing evidence to support approaches to mitigate those risks. This impact is reflected in current UK national policy: the UK Climate Change Risk Assessment (2017) and the National Adaptation Programme (NAP2, Risk PB1, 2018) identify overheating as one of four key climate change risks for people and the built environment that needs urgent action.

4.1 Raising the profile of overheating in buildings at UK government level

Under the 2008 Climate Change Act, the UK government is required to publish a UK-wide Climate Change Risk Assessment (CCRA) every five years. The Act stipulates that the government must assess "the risks for the United Kingdom from the current and predicted impacts of climate change". For the second CCRA, the Department for Environment, Food and Rural Affairs (DEFRA) commissioned an independent evidence report. CBES researchers were contributing authors of the 2016 evidence report published by the Adaptation Sub-Committee (ASC) of the Committee on Climate Change **[1]**. It drew substantially on their research, naming 20 of the group's papers (six on overheating in buildings **[a-f]**), and citing it as the basis for identifying high temperatures as the second most important climate change risk facing the UK. Namely, the report: 1) noted that there are no regulatory or other incentives to ensure existing buildings are retrofitted and for new build developments to be designed and built to limit overheating; and 2) recommended that the urgency of the response be increased to avoid 'lock-in' due to the lack of policy and long lifetime of the residential building stock. The ASC review recognised CBES findings that policy and technological approaches are needed to ensure homes and other buildings are well-insulated for winter, yet sufficiently ventilated in summer to keep internal temperatures down. It acknowledged that future research might show how green infrastructure could reduce the urban heat island effect which can exacerbate climate warming and overheating problems.

<u>Informing UK national assessment of climate-change risks</u>

The ASC report was explicitly addressed in the 2017 UK CCRA. The impact on the UK government was unequivocal: it endorsed the new six priority risk areas identified in the ASC review (of which high temperatures was placed second) and drew on the report's findings. The CCRA acknowledged the significance of a new focus on overheating for policy makers, stating that: "The Government recognises the importance of reducing the risks and impacts of overheating" **[2]**.

<u>Directing UK national policy on climate-change adaptation</u>

The UK National Adaptation Programme (NAP) set out the current and future actions that the government is taking to address the risks and opportunities posed by a changing climate over a five-year period). Where the first NAP contained over 370 actions addressing 100 risks, the government followed research recommendations from the ASC evidence report in the publication of the second UK National Adaptation Programme (NAP2) in 2018, "to set more focused priorities and specific and measurable objectives that clearly contribute to adaptation outcomes, and to be clear on how these will be monitored and evaluated" **[3 p.iii]**. A section of the NAP2 (section 4.5) was devoted to 'Overheating in buildings', drawing on CBES research embedded in the ASC evidence report. This section echoed the findings of CBES research, stating: "We want to ensure that homes and other buildings are well-insulated for winter, while not overheating in the summer. Achieving this aim is likely to require a number of actions, including changes in construction practices, in occupier behaviour and in greater

use of green spaces, including historic parks and gardens, whose role in reducing overheating in urban environments is well documented" **[3, p.51]**.

4.2 Shaping the next generation of UK building regulations for a climate-changed UK
This research has influenced recommendations for UK regulations that will help prevent overheating—particularly in relation to housing stock.

UK Committee on Climate Change's progress report to Parliament
The research informed the UK Committee on Climate Change's progress report to Parliament in June 2017, which recommended that a standard or regulation should be introduced to reduce the risk of overheating in new homes **[4]**. This was reiterated in the committee's 2019 report *UK Housing: Fit for the future?* **[5]** for which Davies was an Adaptation Sub-Committee (ASC) champion. In its 2019 inquiry into heatwaves, the Environmental Audit Committee made the recommendation again, inviting Davies to provide oral evidence **[6]**.

Regulating housing stock to prevent overheating
Mavrogianni provided expert review and guidance on building stock modelling to the 2018 AECOM-led research project on overheating risk in new homes, commissioned by the UK's Ministry for Housing, Communities and Local Government. This is informing its review of relevant Building Regulations. The report states that "[t]o run detailed models on all dwellings in the region however requires significant amount of data and resources. Based on discussions with Symonds and Mavrogianni from UCL it was determined that simulation work by UCL and the London School of Hygiene and Tropical Medicine (LSHTM) using the English Housing Survey (EHS) dataset provides a reasonable estimate of the average indoor temperature for the existing dwelling stock relative to external temperature" **[7, p.31]**.

The Head of Research at the Chartered Institution of Building Services Engineers (CIBSE) summarises the influence that CBES research has had as "fundamental in providing evidence to support national policy such as the National Adaptation Plan and the Climate Change Risk Assessment as well as the follow up UK Housing: Fit for the future? report by the Committee on Climate Change" **[8]**.

Through consultation, lobbying and policy discussions, the Bartlett is providing research to aid the UK Government in addressing climate-change risks associated with high temperatures.

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

1. Kovats, R.S., and Osborn, D., (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 5*, People and the Built Environment*. Contributing authors: Humphrey, K., Thompson, D., Johns. D., Ayres, J., Bates, P., Baylis, M., Bell, S., Church, A., Curtis, S., Davies, M., Depledge, M., Houston, D., Vardoulakis, S., Reynard, N., Watson, J., Mavrogianni, A., Shrubsole, C., Taylor, J., and Whitman, G. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.
2. HM Government (2017) *UK Climate Change Risk Assessment 2017*. See page 13
3. DEFRA (2018) *The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting*. See page 51
4. Committee on Climate Change (2017) *Progress in preparing for climate change: 2017 report to Parliament*. See page 15
5. Committee on Climate Change (2019) *UK housing: Fit for the future?* See page 9
6. House of Commons Environmental Audit Committee (2018) *Heatwaves: adapting to climate change*. https://bit.ly/3cNf3Z9 See page 25.
7. AECOM and MHCLG (2019). Research into overheating in new homes, Phase 2 report. London, UK: AECOM, Ministry of Housing, Communities & Local Government (MHCLG). https://bit.ly/2P2Xyw2 See page 31.
8. Testimonial from Head of Research, CIBSE.