IEA EBC Annex 62 Seminar
Ventilative Cooling: Using the cooling potential of ventilation to reduce energy use in buildings
17th September 2014, Brunel University, Uxbridge

Monitoring summer indoor overheating risk and ventilative cooling behaviour in London homes

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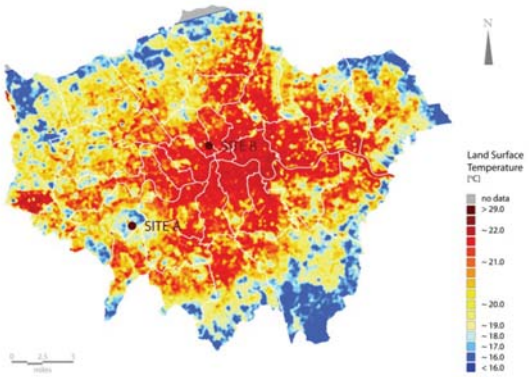
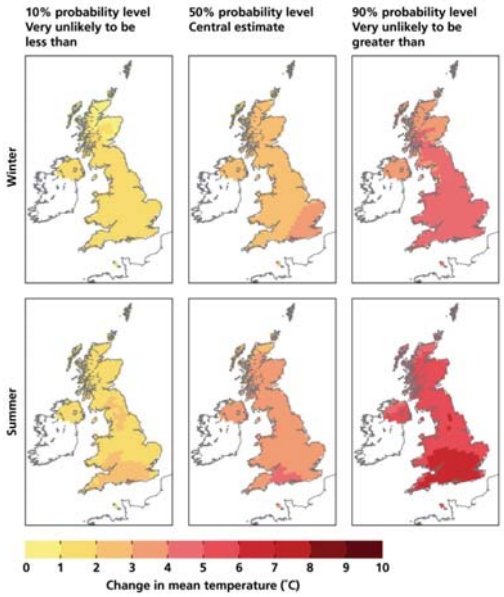
Overview

1 Background

Our **climate is changing** due to humanmade greenhouse gas emissions.

Overheating in cities will be exacerbated due to the **urban heat island** effect.





2080s, Medium Emissions scenario Source: UKCP09

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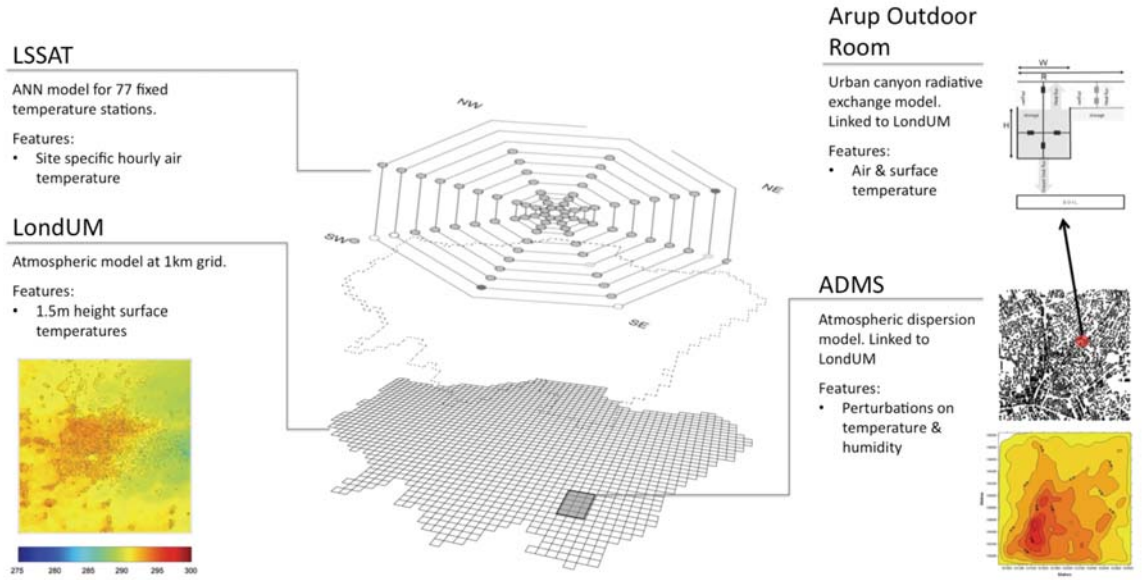
1 Background

Indoor overheating in homes

- Growing body of **evidence**
- Increased **research interest**

2 LUCID: Overview

Modelling the **local urban climate** and its impacts



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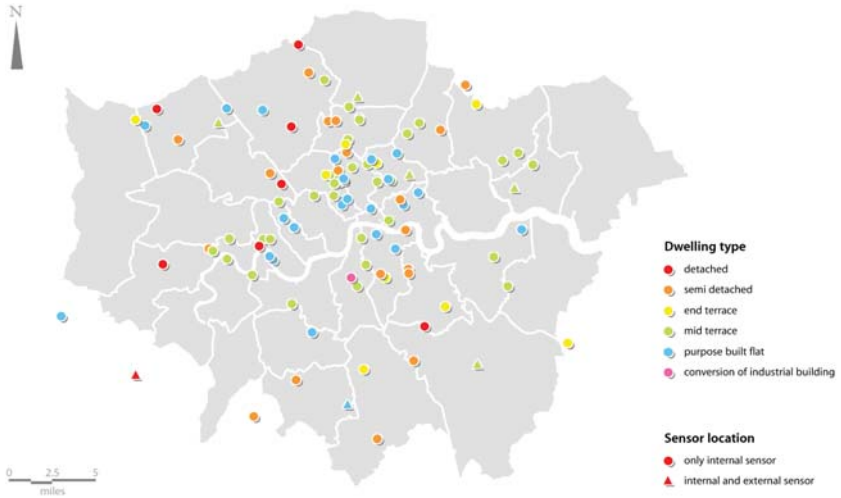
2 LUCID: Monitoring summer indoor overheating

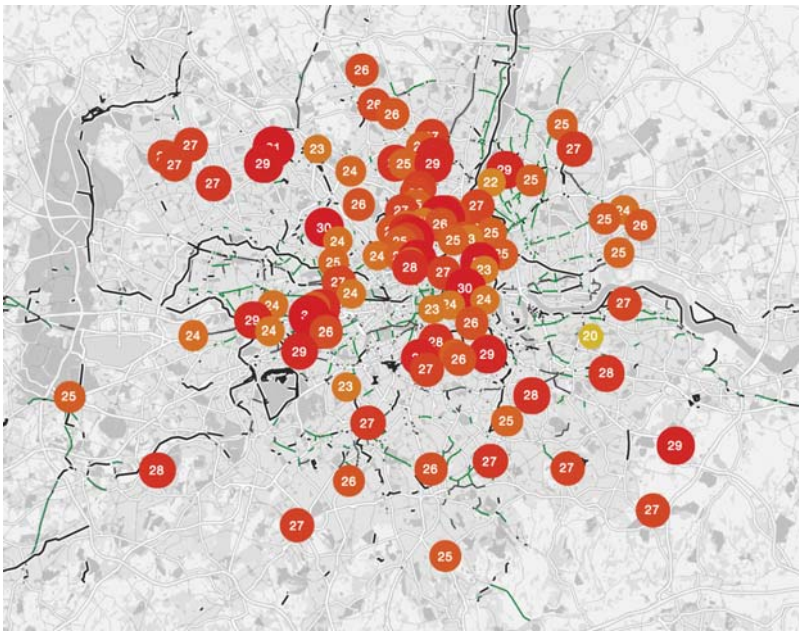
- **101 London dwellings** of varying morphology
- Convenience sample (UCL staff and students)
- Dry bulb **temperature** and relative **humidity** measured during summer 2009 (HOBO U12-012)
- 36 dwellings monitored during **hot spell** (29th June – 3rd July)
- **EPC survey**
- **Energy use and ventilation behaviour questionnaire** (80% response rate)



2 LUCID: Monitoring summer indoor overheating

Full sample
(June-August):

- The analysis of the monitoring data indicated that London homes and, in particular, bedrooms are already at risk of indoor overheating during hot spells under the current climate.
- There is no strong correlation between temperature and distance from the centre.



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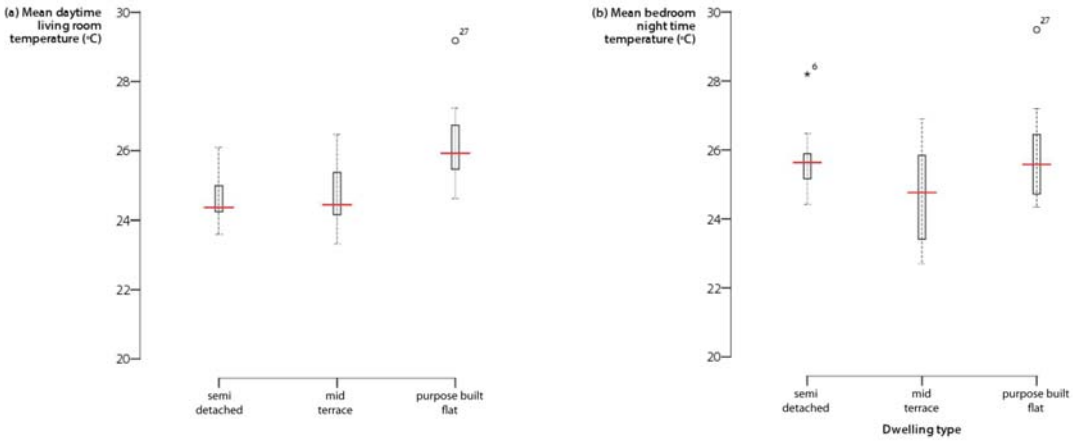
2 LUCID: Monitoring summer indoor overheating



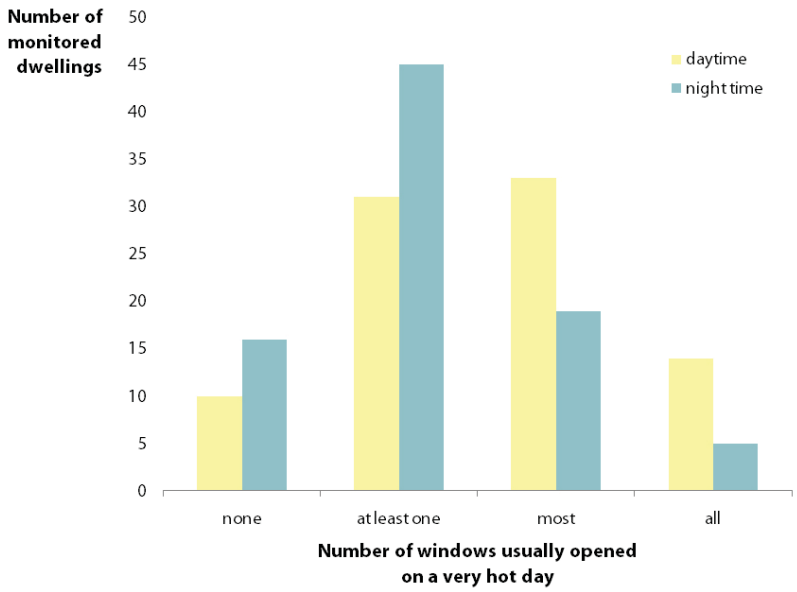
Sub-sample (hot spell):

- Significant levels of night time overheating were recorded in the main bedrooms.
- Sleep impairment due to temperature rising above the 24 ºC threshold might have been caused in 86% (31 out of 36) of the bedrooms.

2 LUCID: Exploring summer ventilation behaviour

Full sample
(June-August):

- Around 70% of respondents open only one or no windows at night (mainly due to security reasons).
- Bedroom air temperatures were slightly higher in dwellings where the occupants tended to leave most or all windows open at night.



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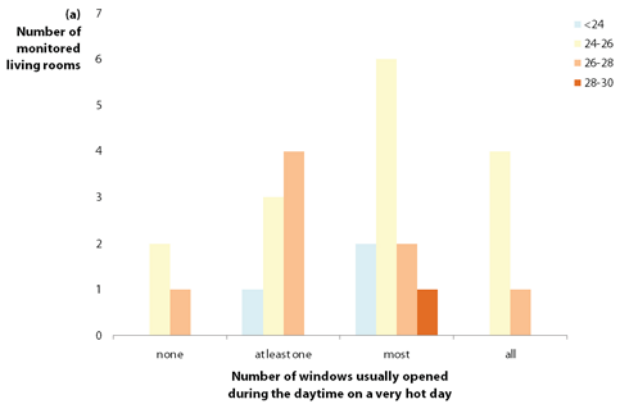
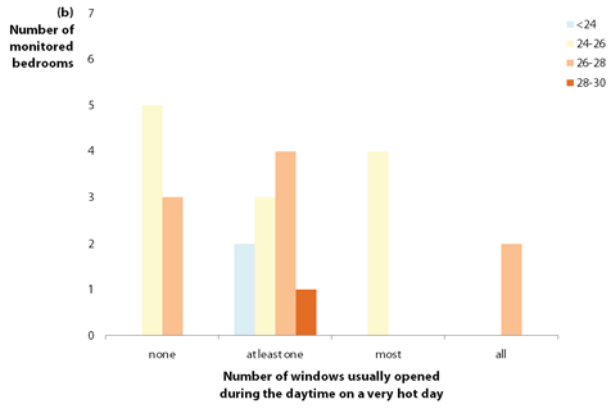
2 LUCID: Exploring summer ventilation behaviour





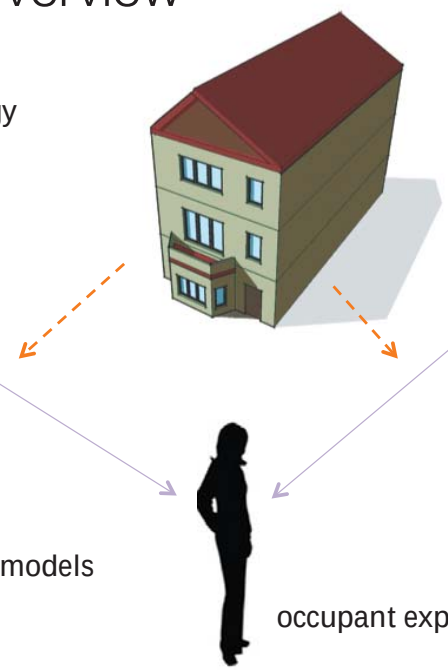
Sub-sample (hot spell):

- Daytime 'rapid' ventilation appears to increase the variability of living room temperatures.
- The effect of night time ventilation cannot be assessed with confidence due to the small sample of houses that left their windows open during the night (mainly due to security reasons).

3 AWESOME: Overview

1. Air pollution and meteorology
- measurements
- spatio-temporal models

NO_x $PM_{2.5}$ O_3



Effect modification
2. Models of building performance (temperature, indoor pollutants)

Temperature

- mortality
- morbidity

occupant exposure

Analyses
3. Time-space epidemiological models
4. Decision analysis
5. Health impact models

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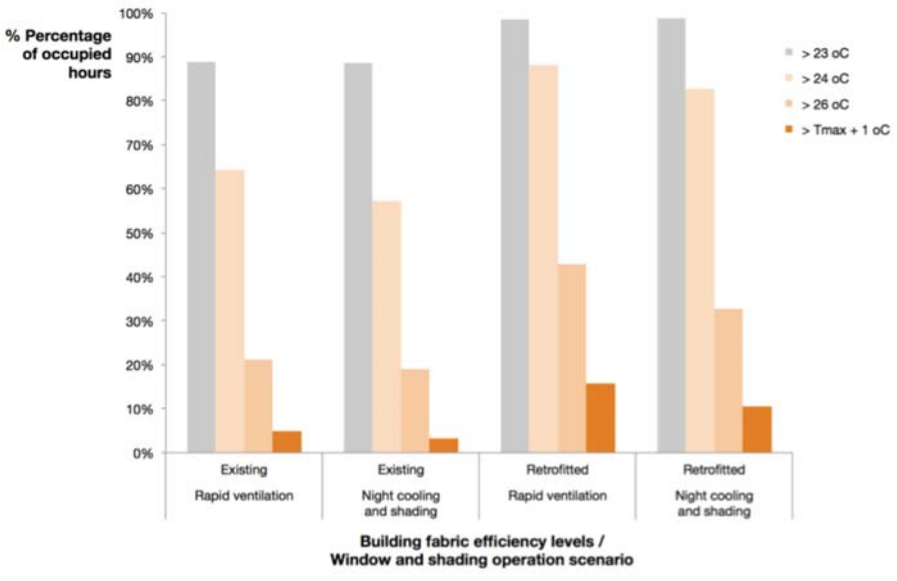
3 AWESOME: Modelling summer indoor overheating

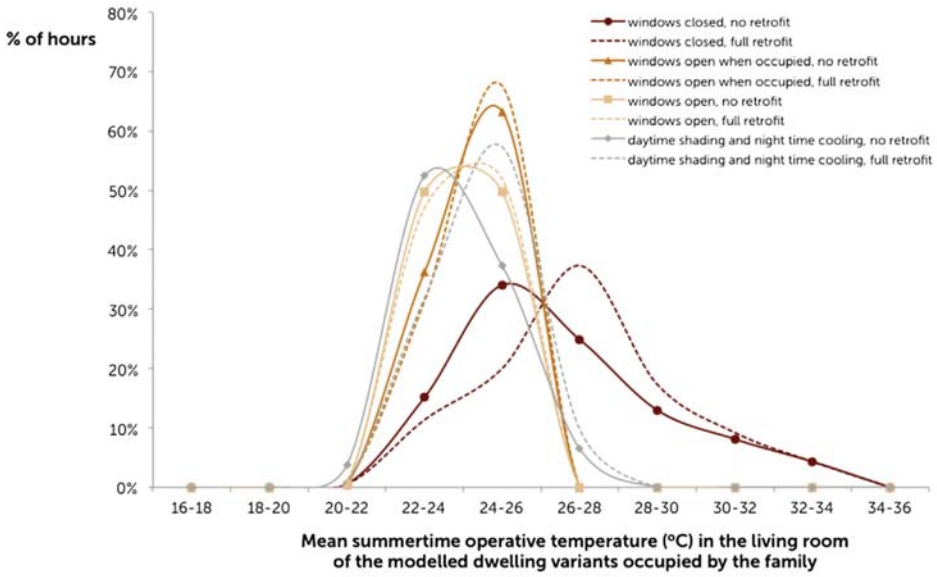
Modelling of a 1960s mid-floor purpose-built flat (bedroom, Medium emissions, 50th percentile, 2050s):
- **Energy efficient retrofit** may increase summer overheating.
- Small temperature reductions in the bedroom as a result of **night cooling** and **internal shading**.



3 AWESOME: Modelling summer indoor overheating

Modelling of London dwelling archetypes (living rooms, current climate):

- Overheating rankings vary as a function of **occupancy patterns, window opening and shading use**.
- Daytime **internal shading** and **night cooling** can modify overheating risk but only to a certain extent.



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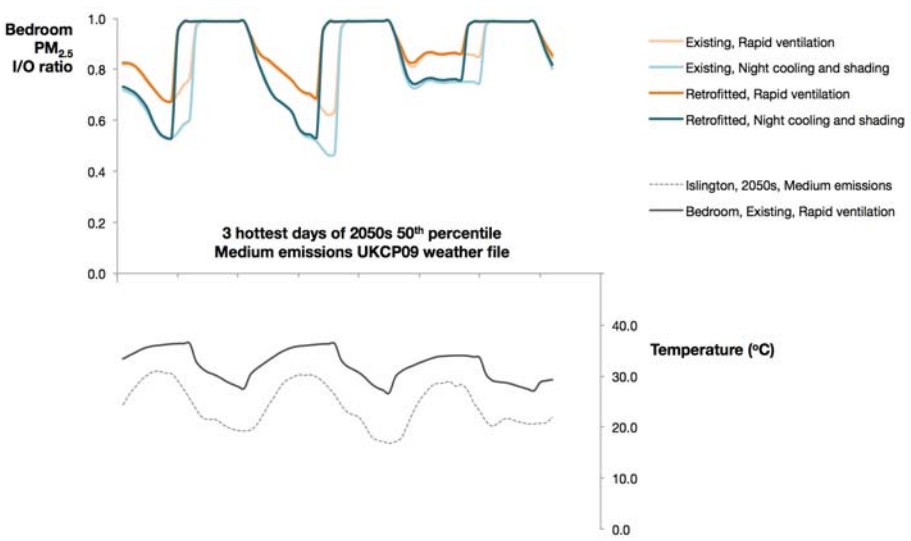
3 AWESOME: Modelling summer indoor air quality

Modelling of a 1960s mid-floor purpose-built flat (bedroom, Medium emissions, 50th percentile, 2050s):

- There are trade-offs between **thermal comfort** and **indoor air quality**:
- Bedroom internal temperatures rise above the window opening threshold, which causes PM2.5 I/O ratios to approach 1.0 due to the ingress of outdoor air.



4 Conclusions

- London homes **already experience** hours with **temperatures above the recommended thresholds**, even during relatively mild summers.
- In the future, such risks are likely to be exacerbated due to **climate change** and certain **retrofit** measures (increased airtightness, internal wall insulation).
- No strong correlations between distance from the centre and overheating risk were observed, which may be an indication that **building characteristics** and **occupant behaviour** may be more important for overheating than the location within the **urban heat island**.
- **Natural ventilation** alone may not suffice to keep indoor thermal conditions within acceptable limits and its cooling potential may be further limited due to **noise**, **security** and **outdoor air pollution** concerns.
- Rankings of dwellings based on their propensity to overheat vary as a function of **occupancy patterns**, **window opening** and **shading use** behaviour.

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4 Ongoing and suggested future research

- Carrying out a large-scale summer thermal monitoring study of statistically representative UK dwellings, potentially including **thermal diaries** and **occupancy sensors**, including information on **window size** and **local wind speeds**.
- Including a detailed comparison of the **static vs. adaptive** thermal comfort approach.
- Further exploring the complex interrelationships between the **indoor thermal environment** and **airborne contaminant transport** in heat vulnerable urban homes.
- Linking markers of exposure to indoor excess temperatures and pollutants with **health markers** (morbidity and mortality data) to assess the **modifying effect of the indoor environment**.

Publications

Journal papers

- Mavrogianni A., Davies M., Wilkinson P., Pathan A. *London housing and climate change: Impact on comfort and health*. Open House International. 2010; 35(2): 49-59.
- Mavrogianni A., Wilkinson P., Davies M., Biddulph P., Oikonomou E. *Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings*. Building and Environment. 2012; 55: 117-30.
- Taylor J., Davies M., Mavrogianni A., Chalabi Z., Biddulph P., Oikonomou E., Das P., Jones B. *The relative importance of input weather data for indoor overheating risk assessment in London dwellings*. Building and Environment. 2014; 76: 81-91.
- Mavrogianni A., Davies M., Taylor J., Chalabi Z., Biddulph P., Oikonomou E., Das P., Jones B. *The impact of occupancy patterns, occupant-controlled ventilation and shading on indoor overheating risk in domestic environments*. Building and Environment. 2014; 78: 183-198.
- Taylor J., Shrubsole C., Davies M., Vardoulakis S., Das P., Mavrogianni A., Oikonomou E. *The modifying effect of the building envelope on population exposure to PM2.5 from outdoor sources*. Indoor Air. 2014; Available online.
- Mavrogianni A., Taylor J., Thoua C., Davies M., Kolm-Murray J. *Urban social housing resilience to excess summer heat and pollution*. Building Research and Information. 2014; Under review.
- Taylor J., Mavrogianni A., Davies M., Das P., Shrubsole C. *Understanding and mitigating overheating and indoor pollution risks using coupled temperature and indoor air quality models*. Building Services Engineering Research and Technology. 2014; Under review.

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Publications

Conference papers

- Mavrogianni A., Davies M., Taylor J., Raslan R., Oikonomou E., Biddulph P., Das P., Jones B., Shrubsole C. *Assessing heat-related thermal discomfort and indoor pollutant exposure risk in purpose-built flats in an urban area*. In: International Conference on Solar Energy Applications to Buildings, Conference internationale Energie Solaire et BATiment (CISBAT) - International Conference on Clean Technology for Smart Cities and Buildings: From Nano to Urban Scale; 4-6 September 2013; Lausanne, Switzerland
- Mavrogianni A., Davies M., Taylor J., Raslan R., Oikonomou E., Biddulph P., Das P., Jones B., Shrubsole C. *The unintended consequences of energy efficient retrofit on indoor air pollution and overheating risk in a typical Edwardian mid-terraced house*. In: FutureBuild - International Conference; 4-6 September 2013; University of Bath, Bath, UK.
- Mavrogianni A., Taylor J., Thoua C., Davies M., Kolm-Murray J. *A coupled summer thermal comfort and indoor air quality model of urban high-rise housing*. In: 8th Windsor Conference: Counting the Cost of Comfort in a Changing World; 10-13 April 2014. Cumberland Lodge, Windsor, UK.
- Taylor J., Biddulph P., Mavrogianni A., Altamirano-Medina H., Shrubsole C., Das P., Davies M. *A novel post-processing contaminant transport and decay model for EnergyPlus*. In: International Building Performance Simulation Association - England (IBPSA-England) Conference - Building Simulation and Optimisation 2014 (BSO14); 23-24 June 2014; UCL, London, UK.
- Taylor J., Davies M., Wilkinson P., Mavrogianni A., Milner J., Shrubsole C., Das P., Chalabi Z. *Modelling the modifying effect of homes on population exposure to pollution*. In: International Society for Environmental Epidemiology (ISEE) 26th Conference; 24-28 August 2014; Seattle, Washington, USA.

Thank you!

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Any questions?