London-Loughborough EPSRC CDT
Centre for Doctoral Training in Energy Demand

SUMMERTIME OVERHEATING IN UK HOMES

Can occupants keep cool without using air-conditioning?

Ben Roberts supervised by Dr. David Allinson and Prof. Kevin J. Lomas

LoLo Annual Colloquium 2018

8 November 2018

UCL

Loughborough University

EPSRC Engineering and Physical Sciences Research Council

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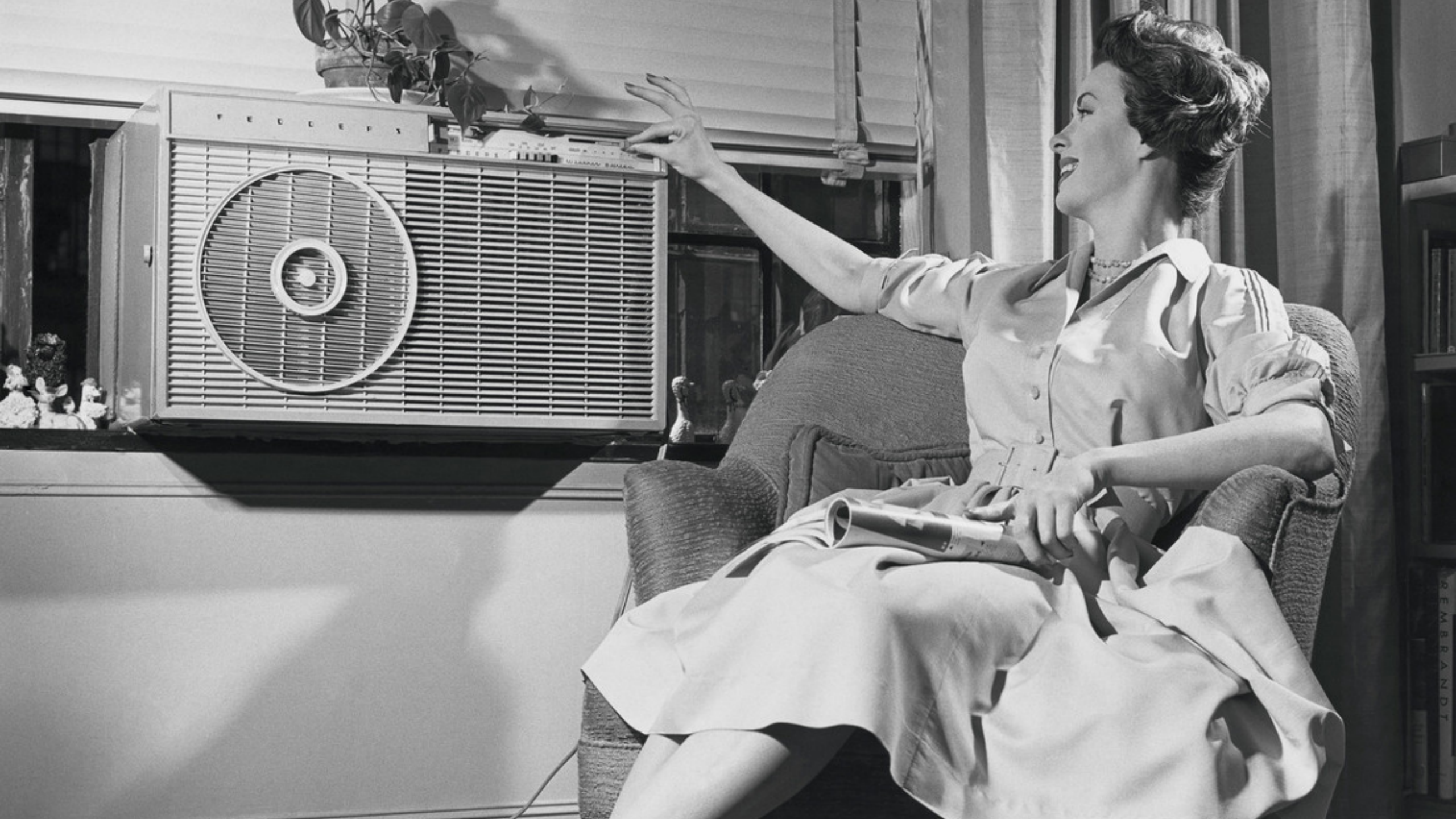
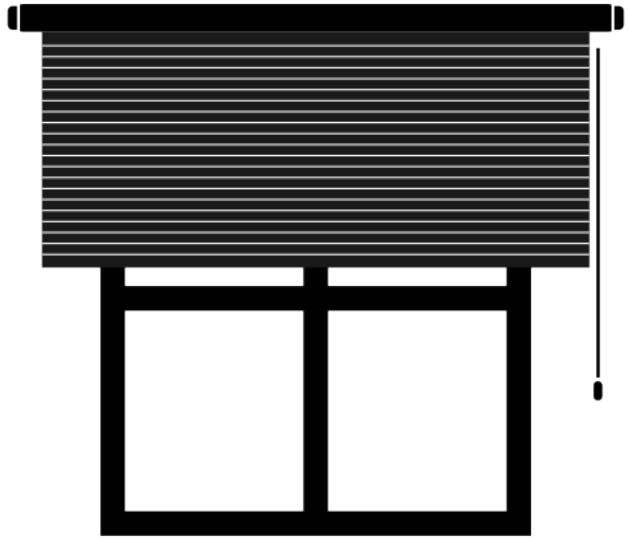




PhD Aim

Can window and curtain use reduce summertime overheating?

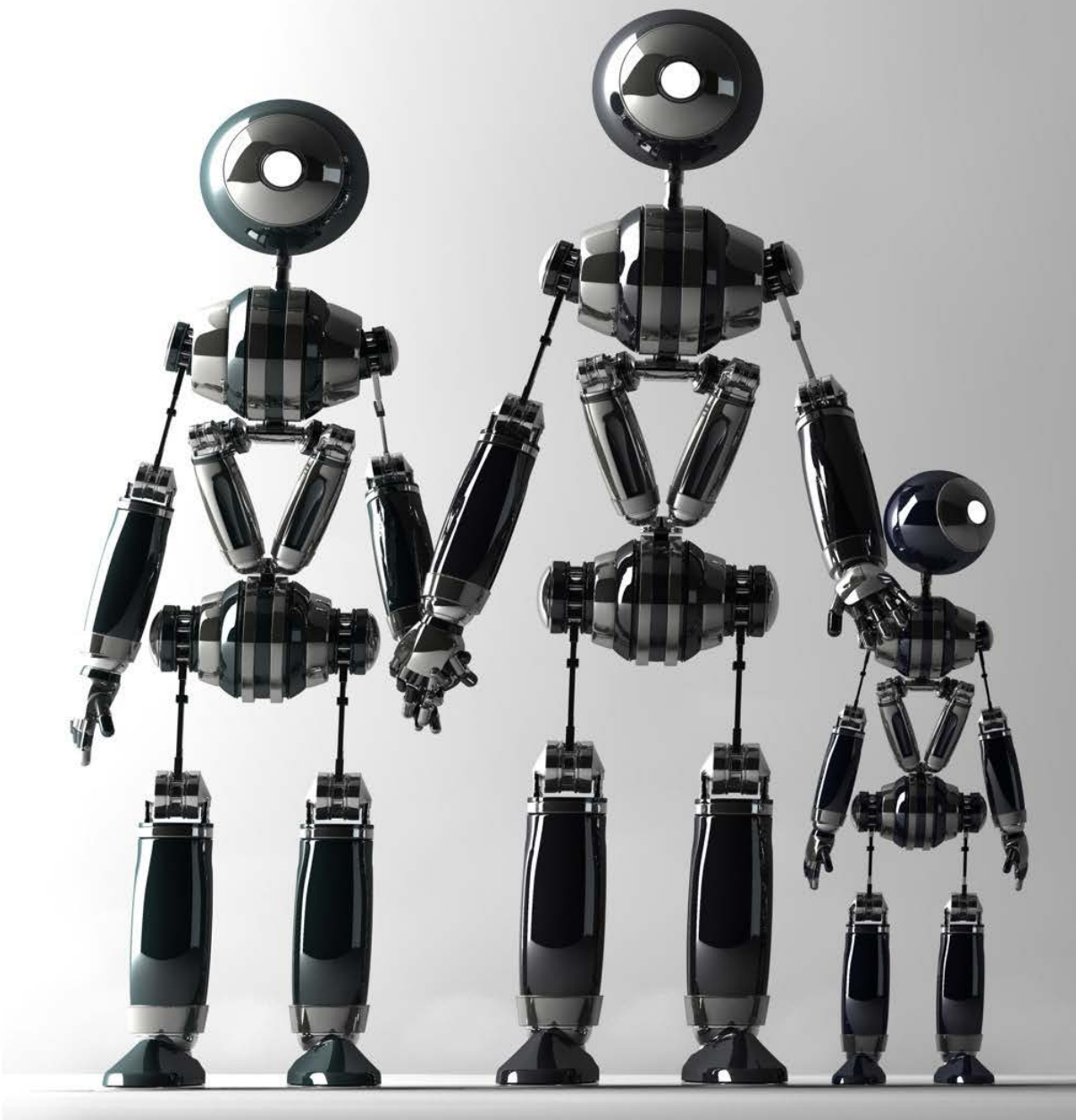

209
207

Synthetic occupancy

- Not real people, but does things people do.
- Controlled
- Repeatable
- Reliable

But...

- Doesn’t perfectly replicate the behaviour of real building occupants.

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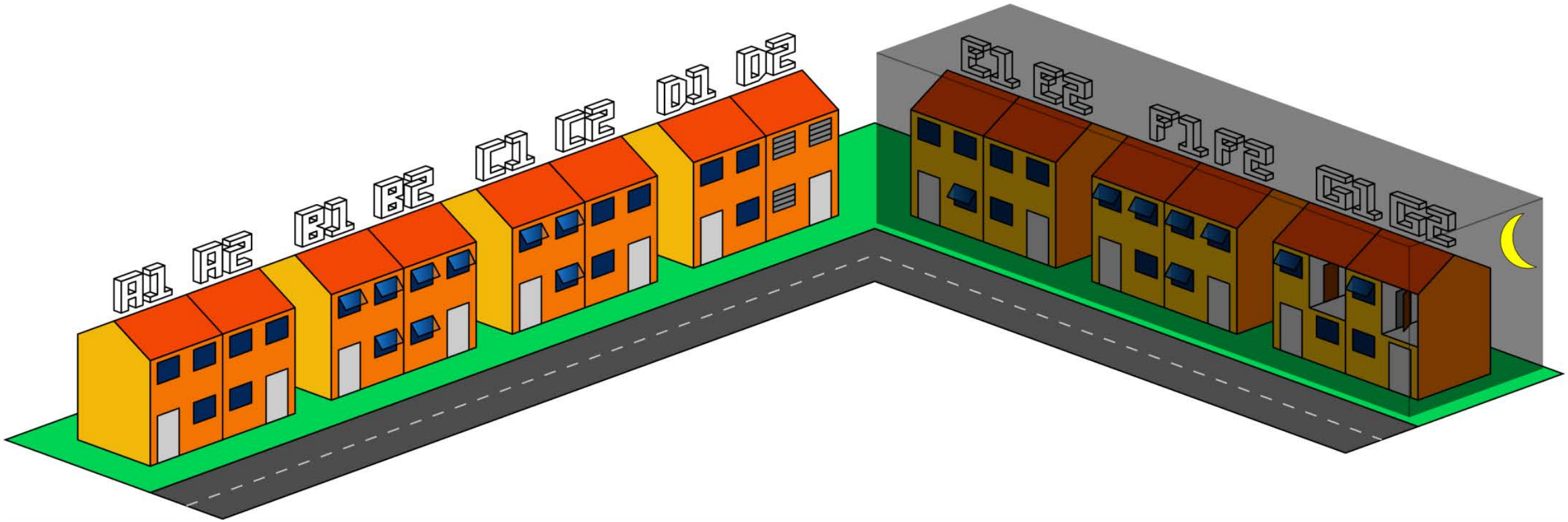
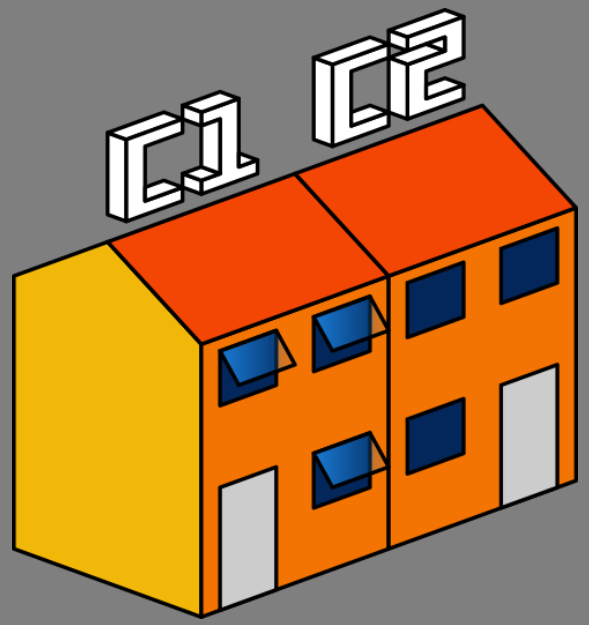
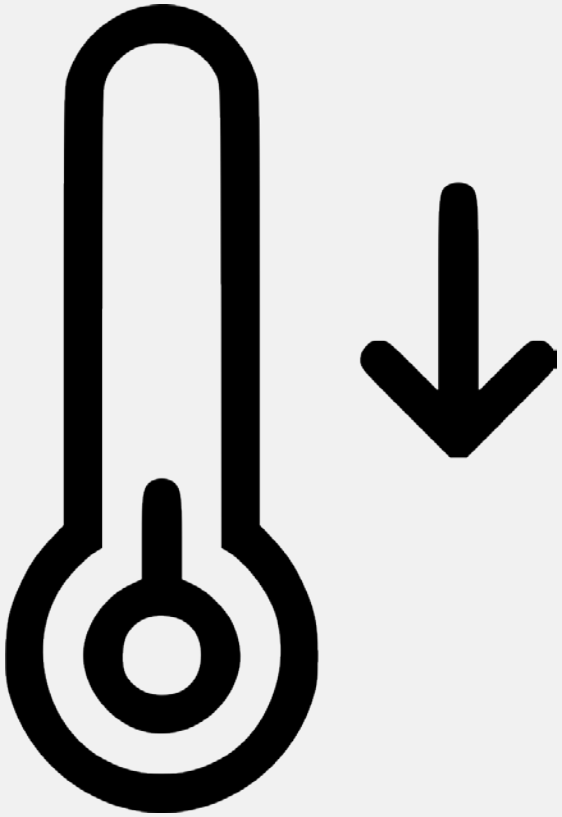


Comparing different occupant behaviours
May-September 2017

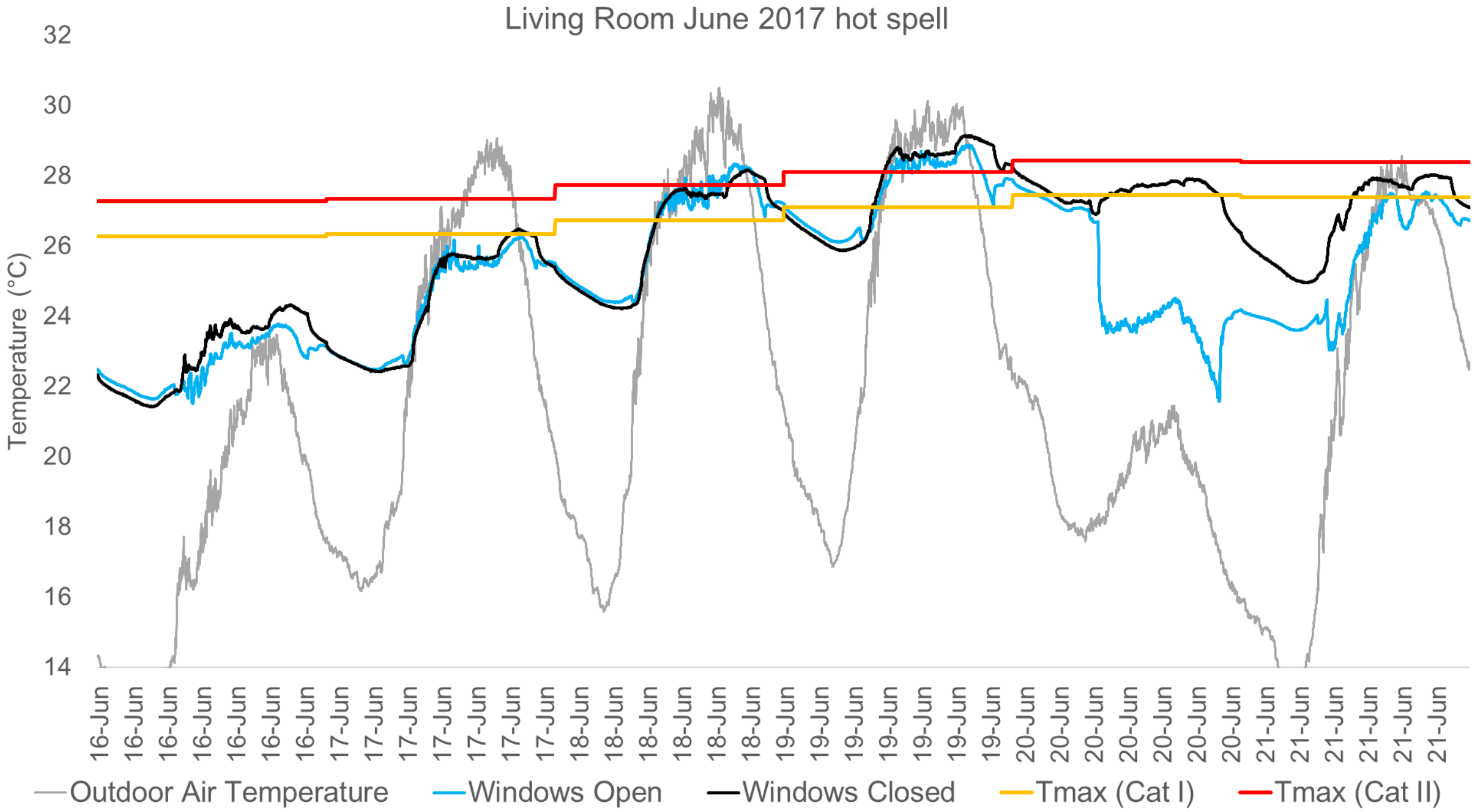
Comparing window opening

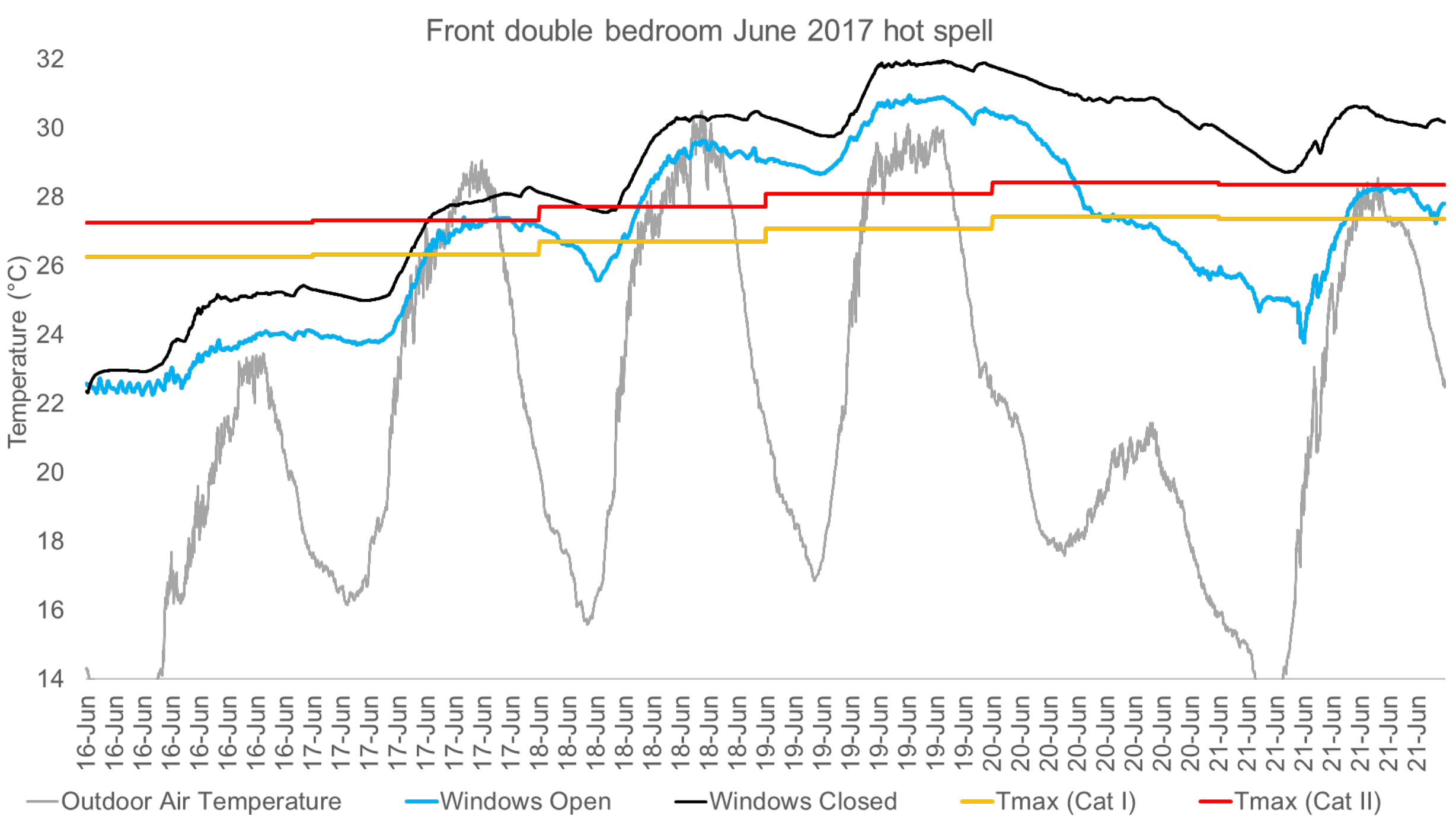




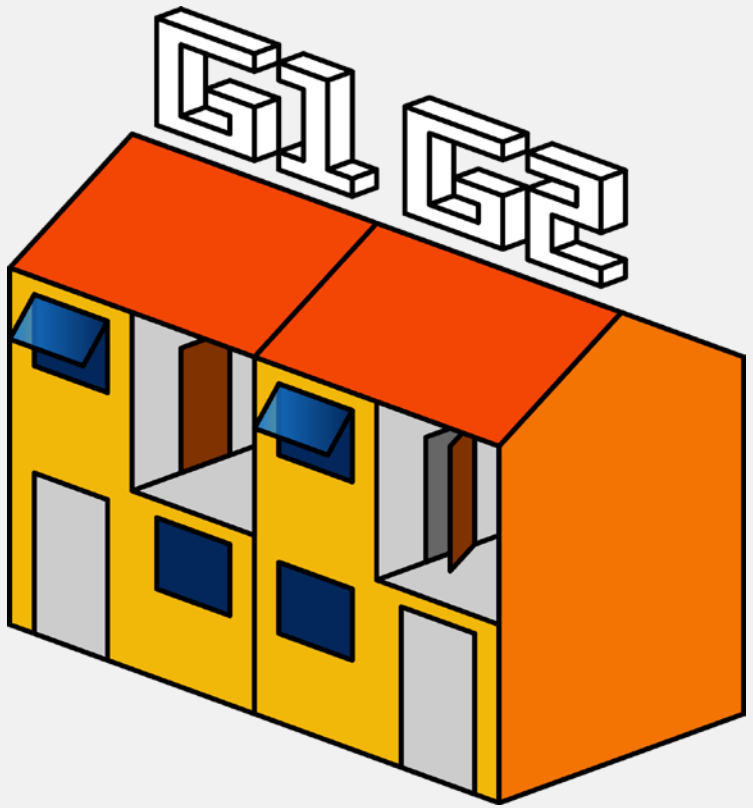
1.5°C

Mean whole-house floor area weighted average 1.5°C reduction in operative temperature by opening windows in occupied rooms when air temperature >22°C over 21 day test period


Living Room June 2017 hot spell
Temperature (°C)
32
30
28
26
24
22
20
18
16
14
16-Jun
17-Jun
18-Jun
19-Jun
20-Jun
21-Jun
Outdoor Air Temperature
Windows Open
Windows Closed
Tmax (Cat I)
Tmax (Cat II)


Front double bedroom June 2017 hot spell
Temperature (°C)
32
30
28
26
24
22
20
18
16
14
16-Jun
17-Jun
18-Jun
19-Jun
20-Jun
21-Jun
Outdoor Air Temperature
Windows Open
Windows Closed
Tmax (Cat I)
Tmax (Cat II)

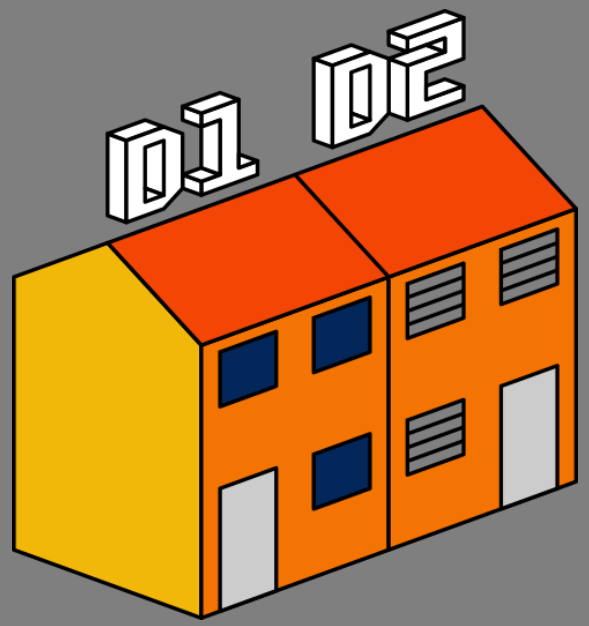
Lower operative temperature with **internal doors open** when night ventilating



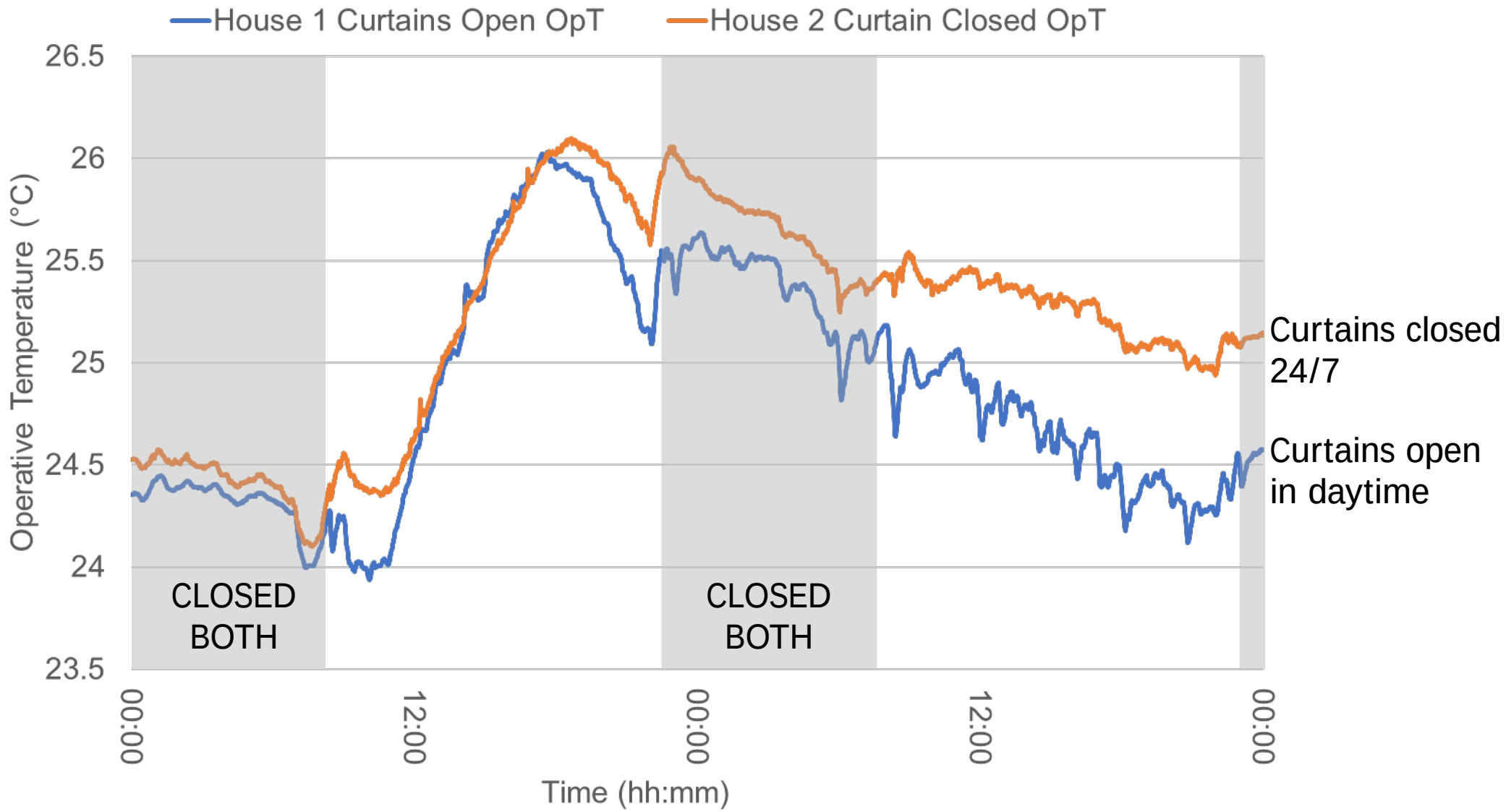
All hours	Sleeping hours
1.3°C	1.7°C

Difference in single bedroom operative temperatures (mean) for 17 day test period.

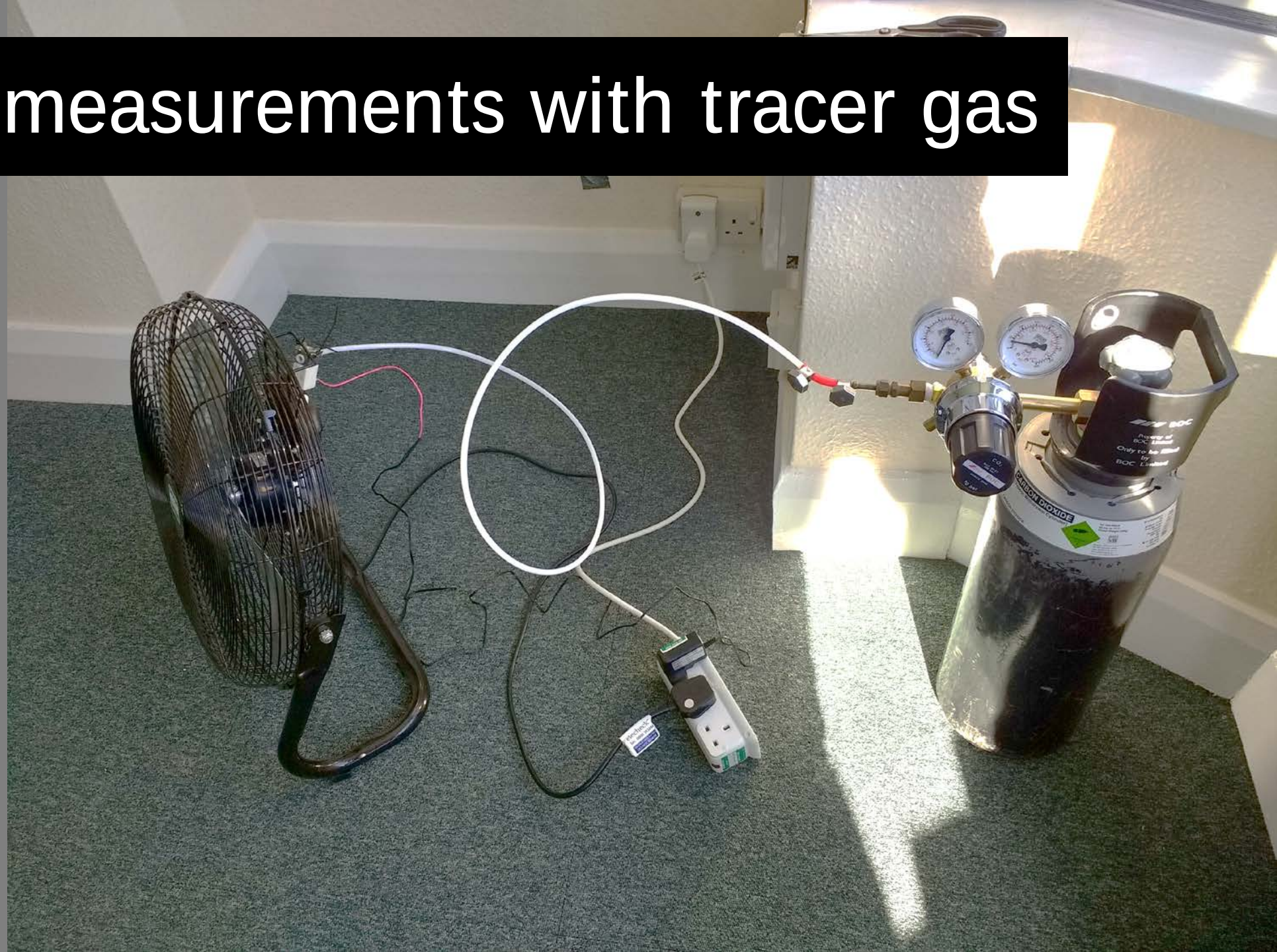
Comparing blind use



A paired t-test showed north-facing bedroom operative temperatures were 0.2-0.4°C lower with **curtains open**.



Ventilation measurements with tracer gas



What can occupants do to reduce ~~overheating~~ indoor temperature?

1. Night ventilate.
2. Open curtains at night.
3. Open bedroom doors.

Industry Continue to develop secure and noise/light-attenuated night ventilation.

Academia New dataset of indoor temperature using CIBSE TM59 occupancy profiles for further analysis.

Policymakers Regulate to enable night ventilation and cross-ventilation in future residential buildings.

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Thank you for listening

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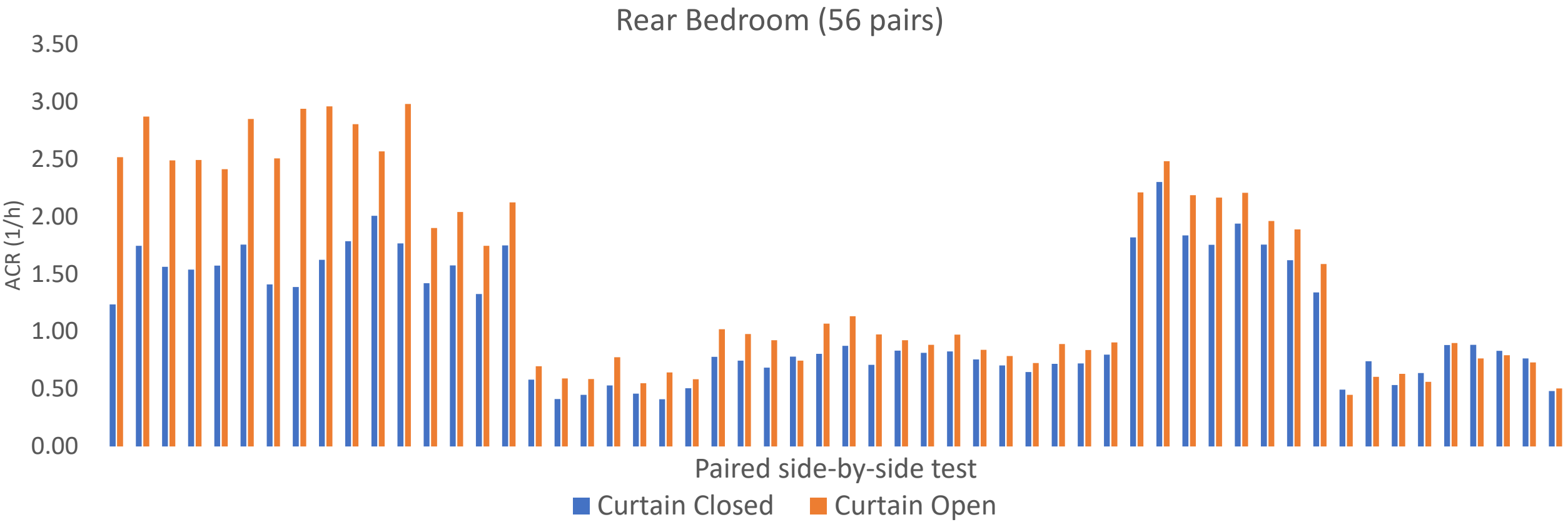
Loughborough
University

Extra information

Lower air change rates with curtains closed

(and windows open)



Paired t-test = **0.25-0.47ac/h difference** curtains open/closed (rear bedroom)

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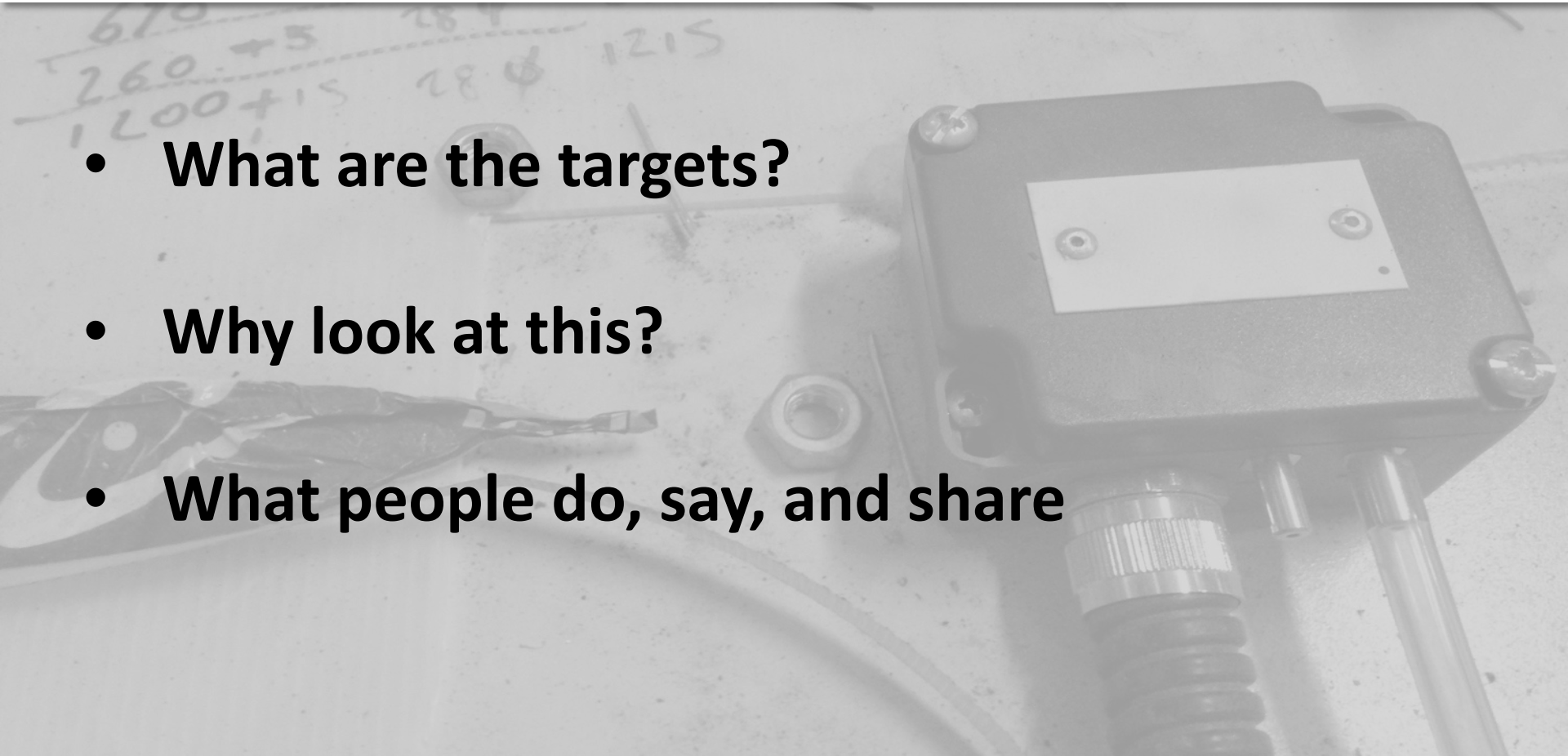
LIFE IN THE GAP:
HOW DOES A CONSTRUCTION TEAM RESPOND TO TARGETS FOR ENERGY AND CARBON IN-USE?

Catherine Willan
Supervisors: Paul Ruyssevelt, Michelle Shipworth, Russell Hitchings

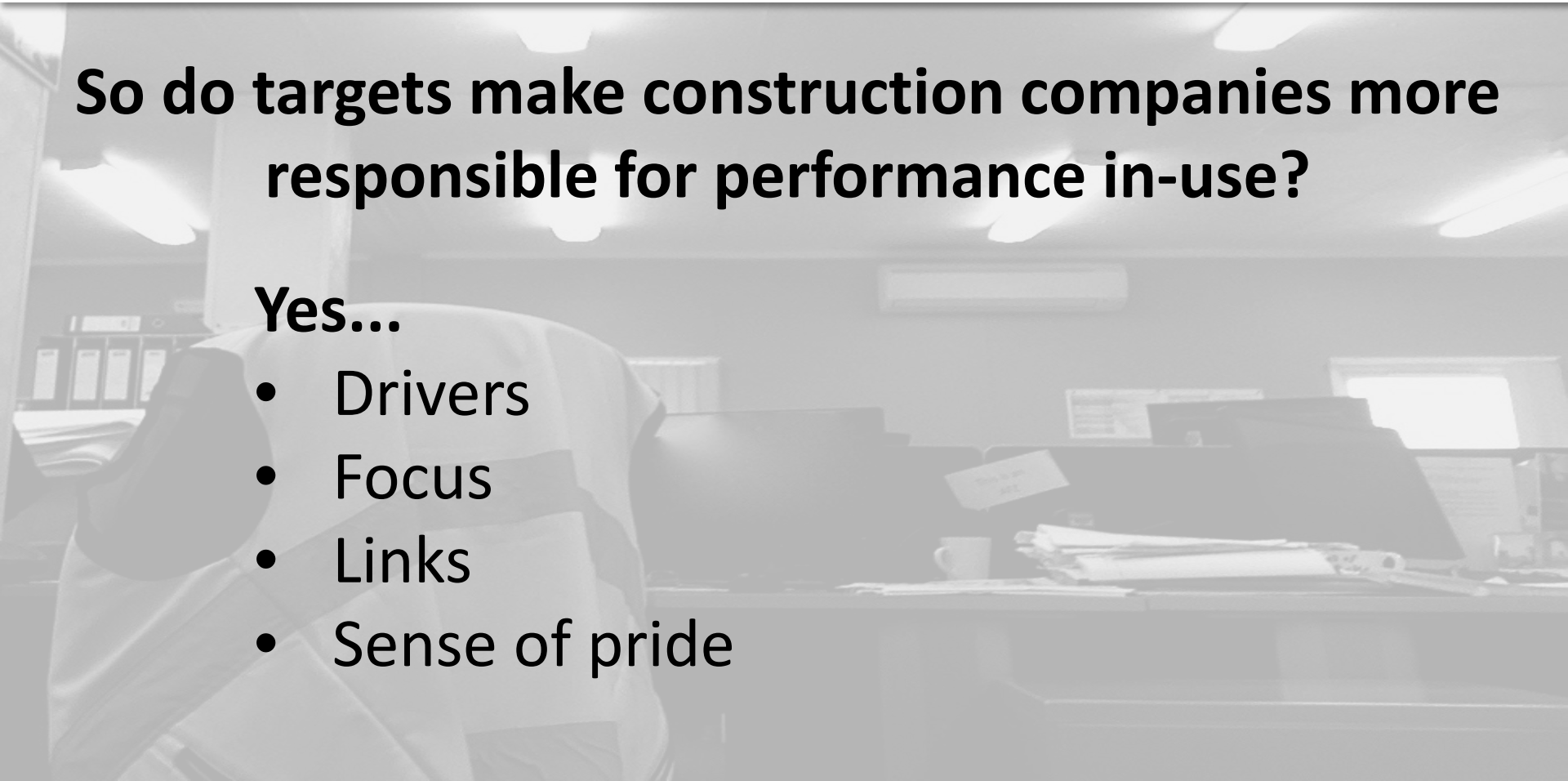
LoLo Annual Colloquium 2018 8th November 2018 @LoLoCDT #lolocdt

"If we don't hit our carbon target, we will be fined" (construction manager)



- What are the targets?
- Why look at this?
- What people do, say, and share

"I'd like to think that you design a system, and it's the best it could be" (contractor)

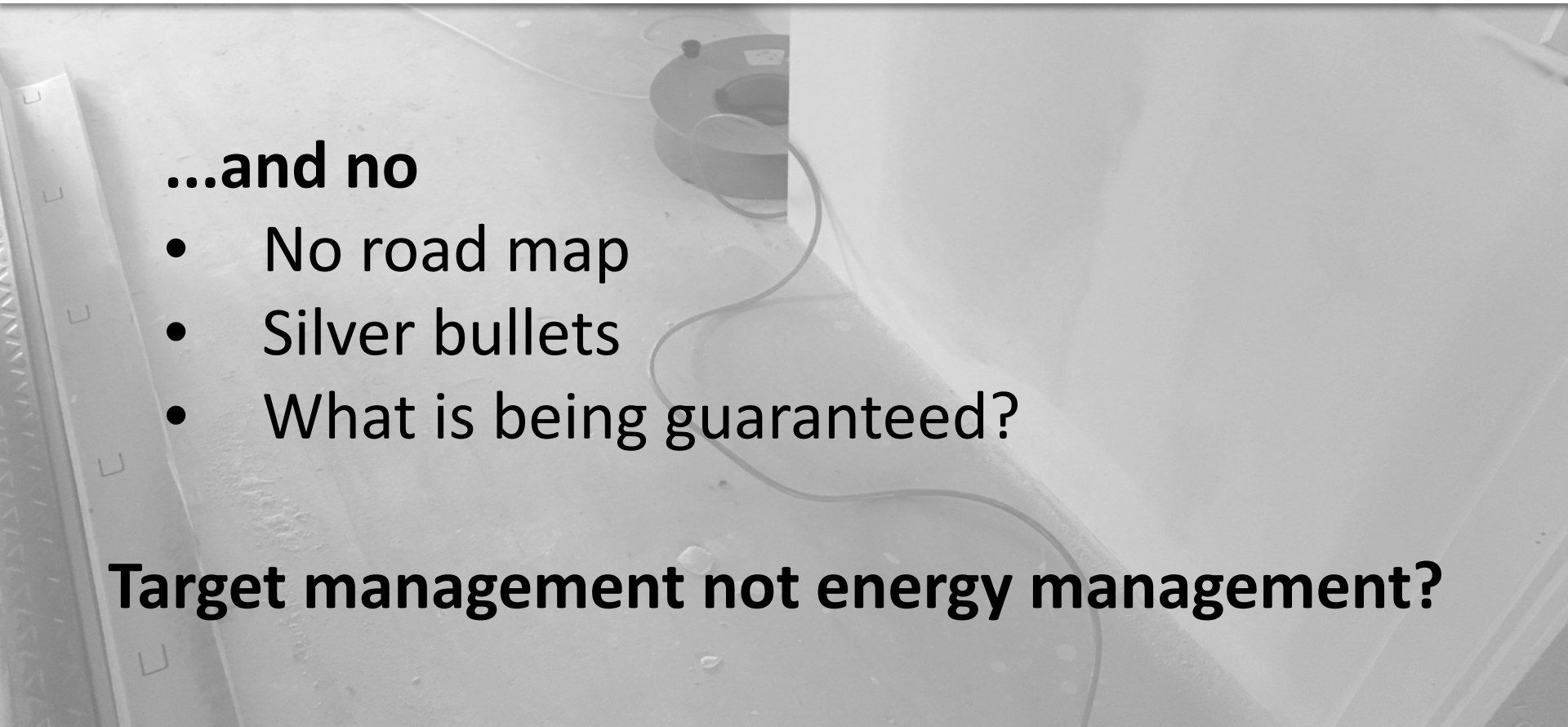


So do targets make construction companies more responsible for performance in-use?

Yes...

- Drivers
- Focus
- Links
- Sense of pride

"As much as ...we want to be [a] green contractor, I'm really looking at risk" (engineer)



...and no

- No road map
- Silver bullets
- What is being guaranteed?

Target management not energy management?

“Remember we're a systems integrator. We don't build...” (head office)

What does this mean for construction?

- Practical guidance
- Consistent responsibility
- Coordination points
- Knowledge and information

"There are no standards – it's not like you can go the ISO standard" (engineer)

Reflections for policy

- Policy in practice
- Standards vs variation
- Contracts and incentives
- Market pull

“You know you've achieved what you think you've achieved” (engineer)

Research perspective:
what is an energy efficient building?

- Reality (“actual use”) is negotiable
- Do targets tell us how well the building did?

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Thank you

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Vision and leadership for a sustainable built environment

DEVELOPING A DYNAMIC METHOD TO ASSESS WHOLE HOUSE HEAT LOSS

Frances Hollick Supervised by Cliff Elwell (1st) Bob Lowe (2nd)

LoLo Annual Colloquium 2018

8 November 2018

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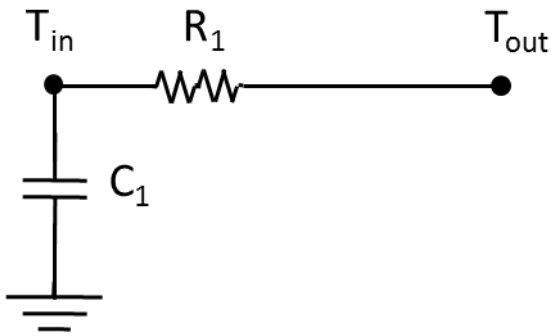
Aims:

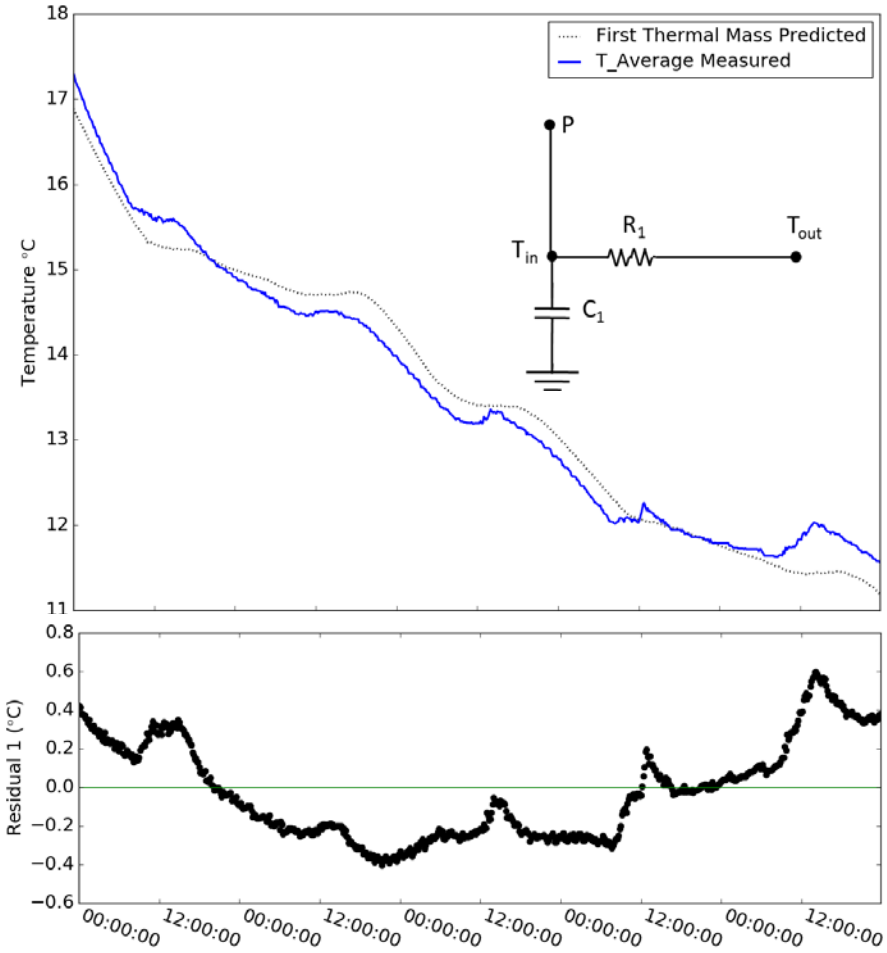
- A widely applicable method of determining the heat loss coefficient of an occupied house
  - As unintrusive as possible
  - Requiring minimal assumptions

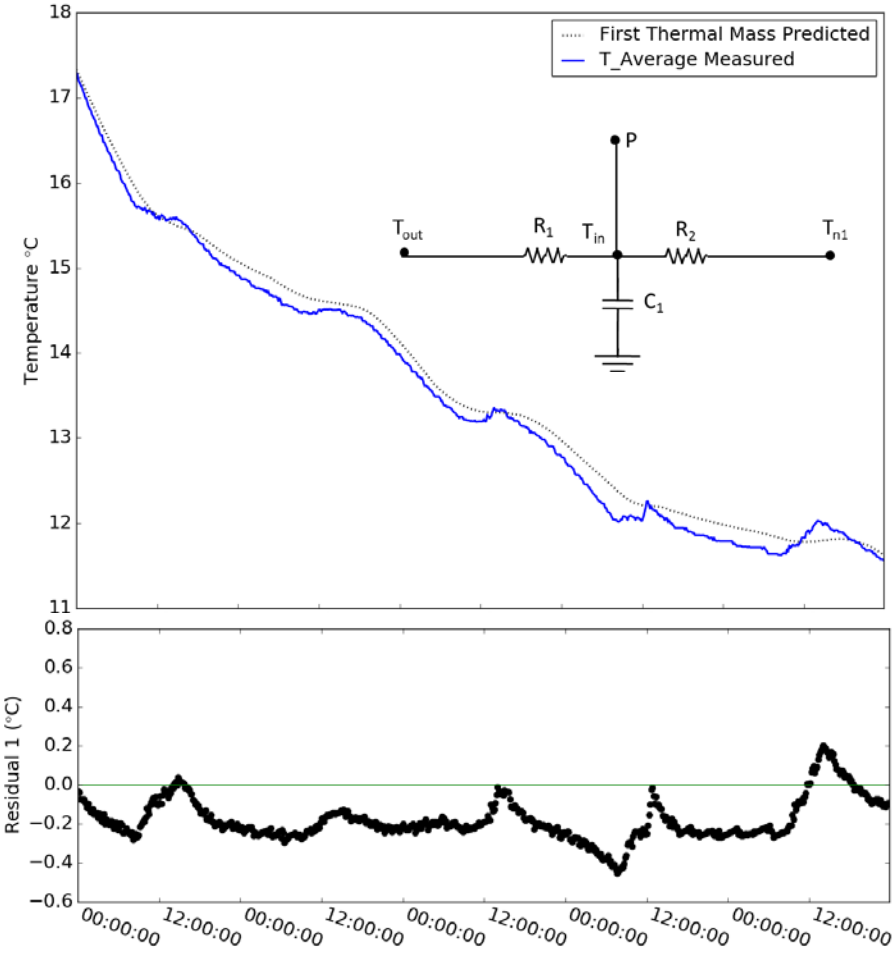


Methods:

- Bayesian analysis of grey box models
- Lumped thermal capacitance models

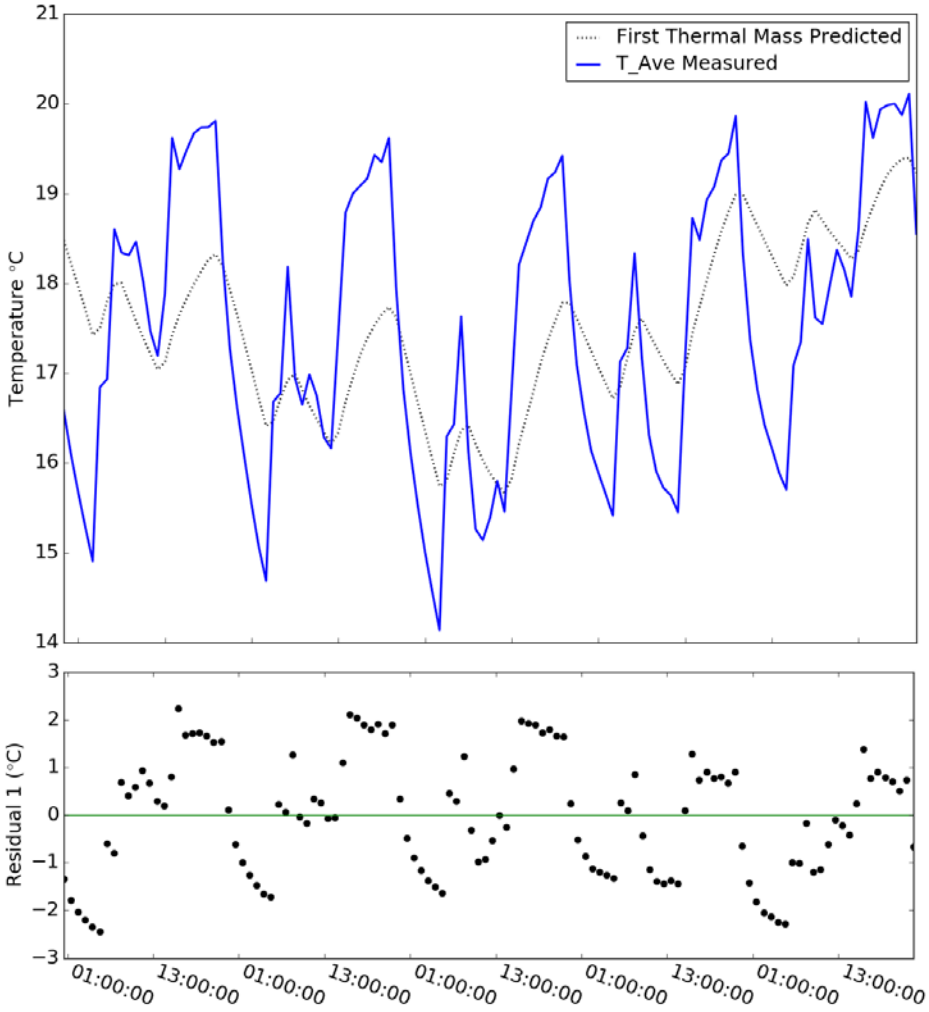
- Around 6 case study houses, all occupied or with synthetic occupancy

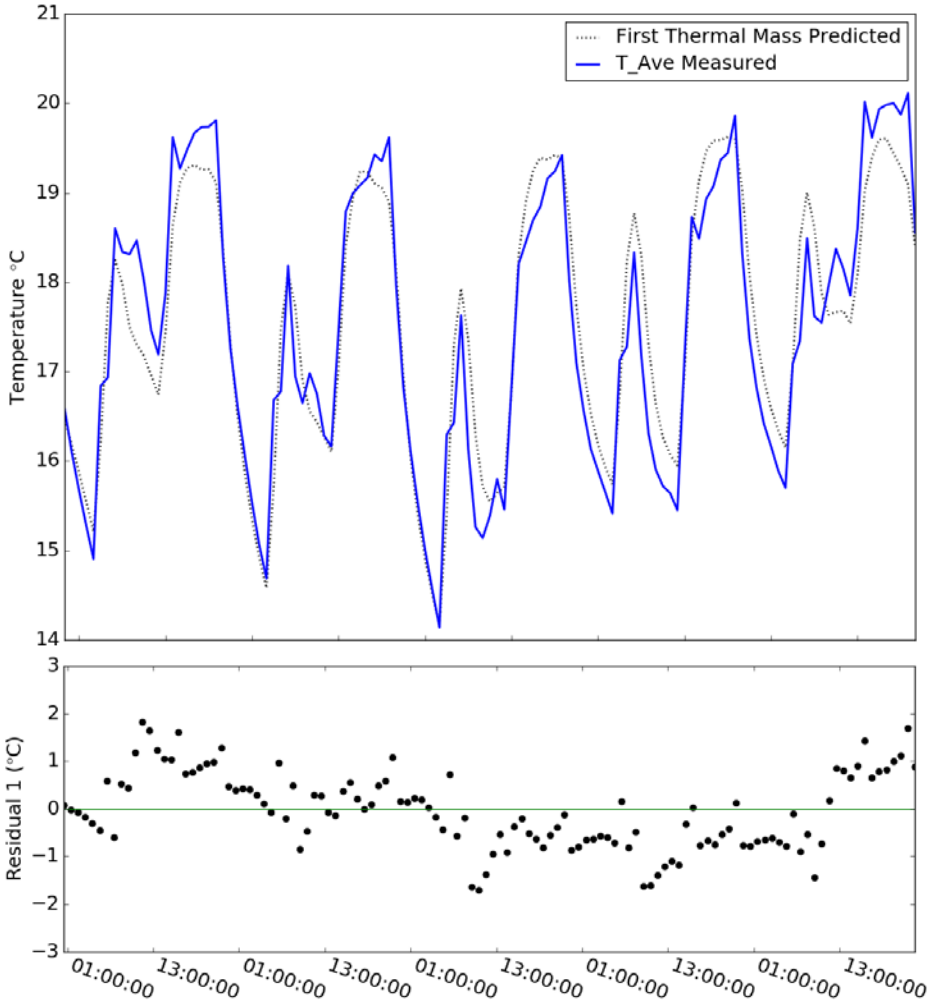




5 unoccupied days in November

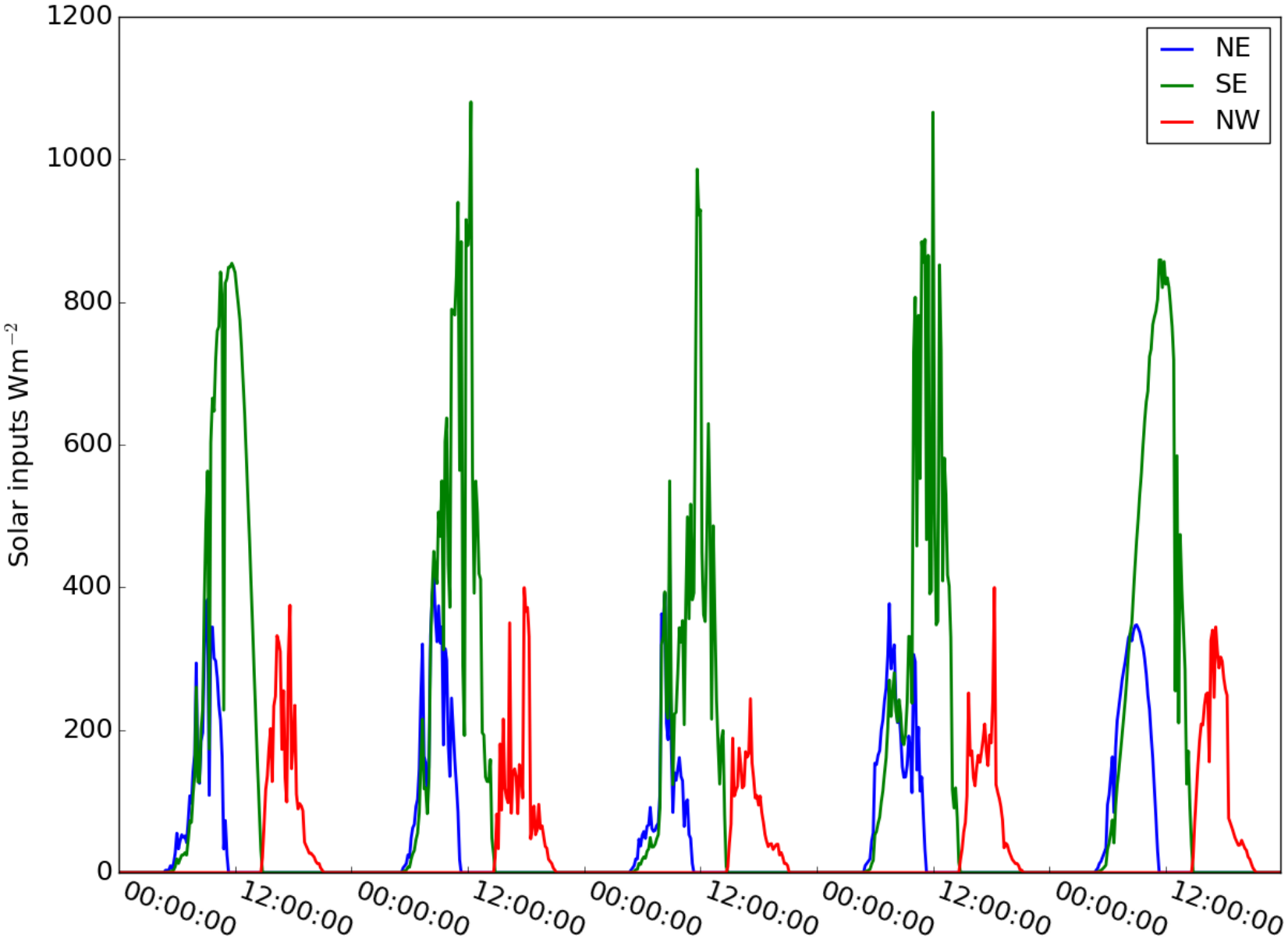
Semi-detached house





5 synthetically-occupied days in March

Semi-detached house


NE
SE
NW
Solar inputs Wm^{-2}
0
200
400
600
800
1000
1200
00:00:00
12:00:00
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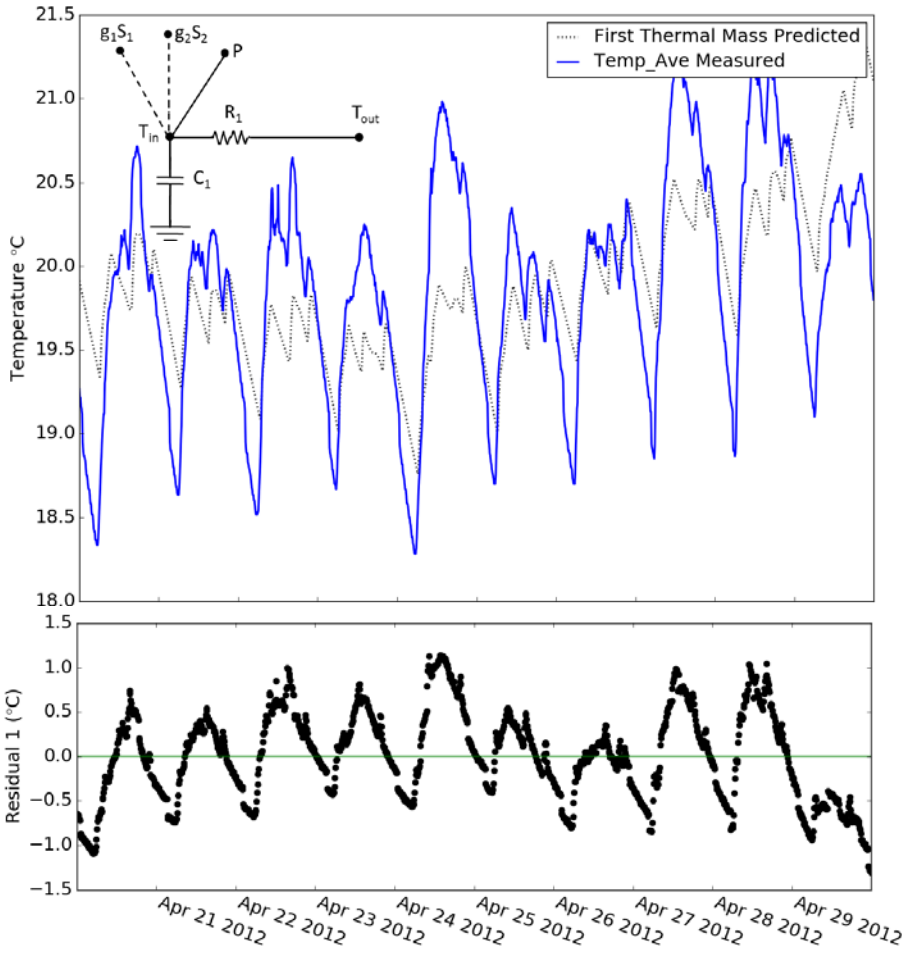

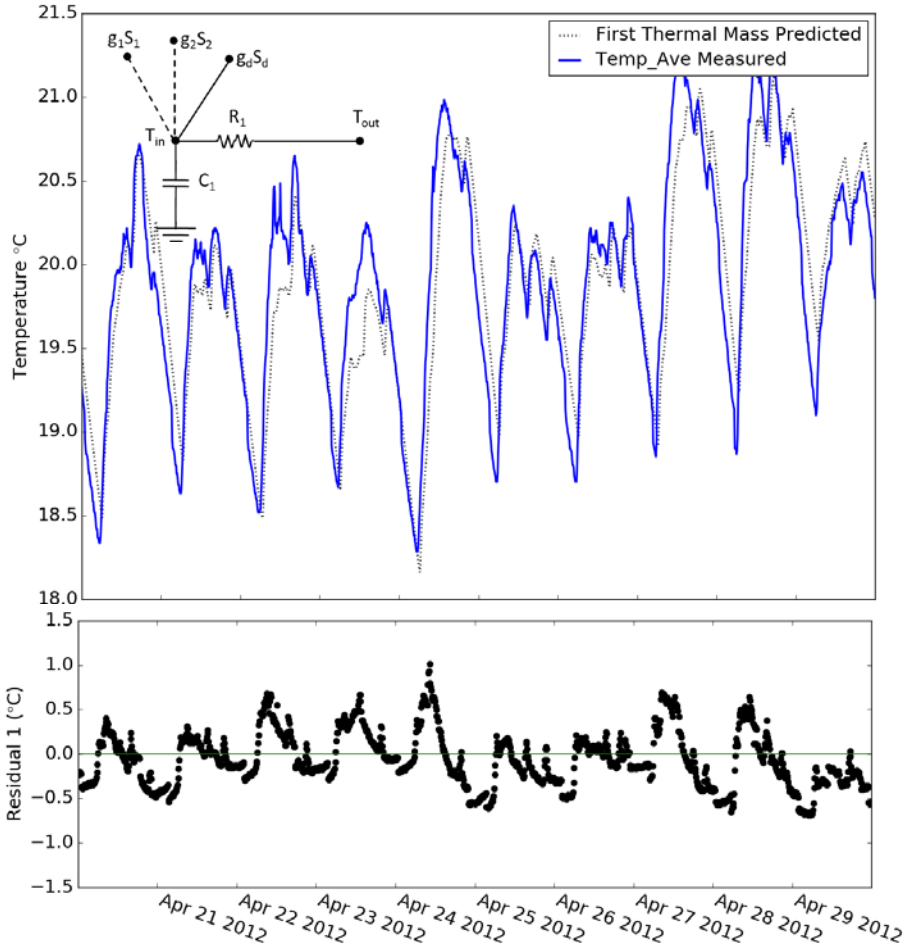

10 synthetically-occupied days in April

Detached house

Insights for academia:

- It is possible to dynamically model an occupied house using internal temperature, smart meter-style energy data and basic weather data
  - Different models are required for different buildings and different times of year

- Dynamic models allow shorter testing periods and year-round data collection

- Characterising water heating becomes more important as fabric efficiency improves; more data is needed to explore this

Insights for industry:

- Models of this form could be incorporated into smart in-home devices
- They could also be used for QA, or to facilitate targeted retrofits

Insights for policy:

- The method could provide a tool to investigate a building's compliance
- It could also support the implementation of retrofitting schemes, and the wider benefits of smart-meter roll out

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Vision and leadership for a sustainable built environment

PREDICTION OF INTERNAL TEMPERATURES DURING HOT SUMMER CONDITIONS WITH TIME SERIES FORECASTING MODELS

Presenter: Matej Gustin, Loughborough University
Supervisors: Dr. Rob McLeod and Prof. Kevin Lomas

LoLo Annual Colloquium 2018
8 November 2018

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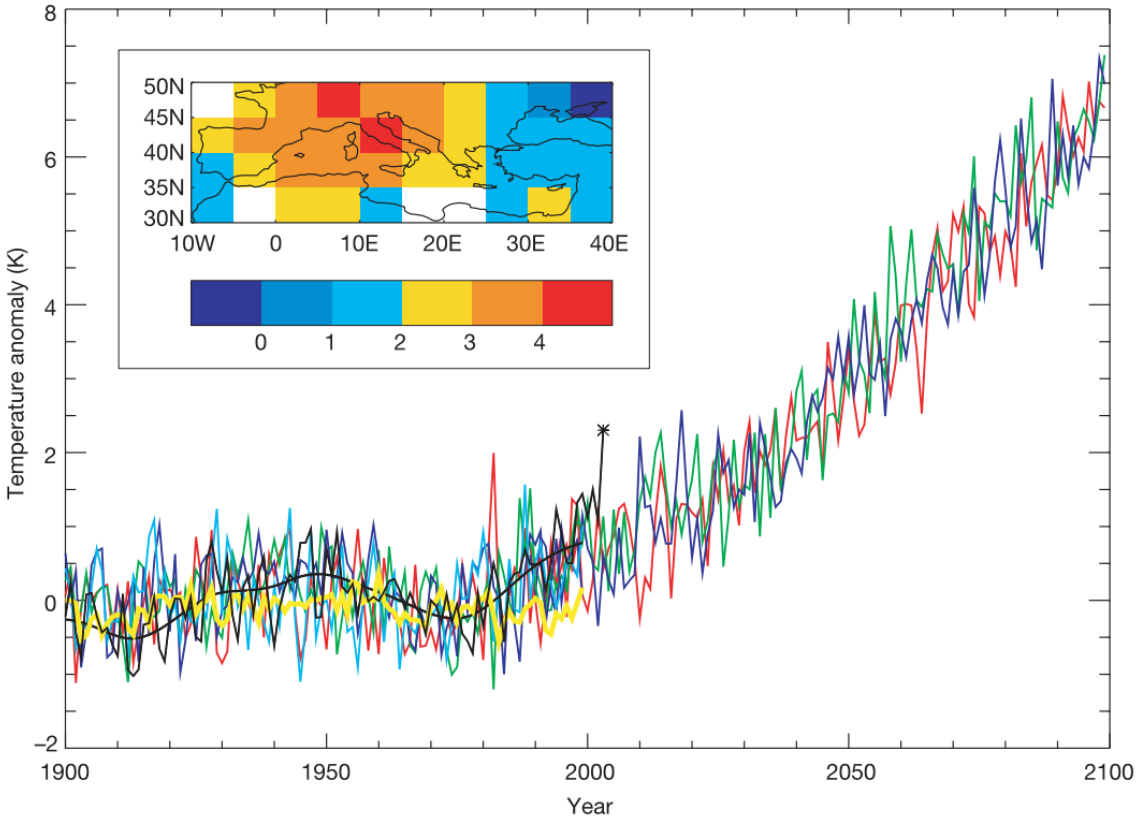
Background

- **Heatwave 2003:** over 2,000 heat-related deaths in the UK and more than 30,000 across Europe [1]
- Such events are predicted to become **more frequent, more intense and longer lasting** due to climate change [2-3]
- **Heatwave 2018:** unusual heatwaves and record breaking temperatures in Northern Europe [4]



Summer temperature anomalies, Stott et. al. (2004, Nature): [5]

Context

- Following 2003 heatwave **Heat-Health Warning Systems (HHWSs)** were adopted in 16 European countries, warnings based on **external air temperature** [6-7]
- **Individuals situated indoors are 1.7-3.8 times more likely to experience adverse conditions** than individuals located outdoors [8]
- People **spend most of their time indoors** [9]
- **People aged over 60 years** and individuals with **chronic diseases** at increased risk [10]
- Over-reliance on **air conditioning is unsustainable** and not widely affordable [11]
- Development of local, **dwelling-based internal thresholds**, should be a priority [12]

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Project title, aim and objectives of the projects

Project title: PREDICTING OVERHEATING RISK IN UK HOMES

Aim: *to develop an empirical forecasting model for the short-term prediction of the indoor temperatures in free-running existing dwellings during hot summer conditions*

Objectives:

- Develop model able to operate during extreme events (i.e. heatwaves)
- Automate selection of optimal model structure (i.e. input variables)
- Create model which operates continuously with a rolling forecasting origin
- Evaluating how far in advance the model can forecast with adequate accuracy
- Test linear and semi-parametric models (e.g. ARX and GAM) RStudio
- Evaluating stochastic effect of interventions (e.g. window opening)

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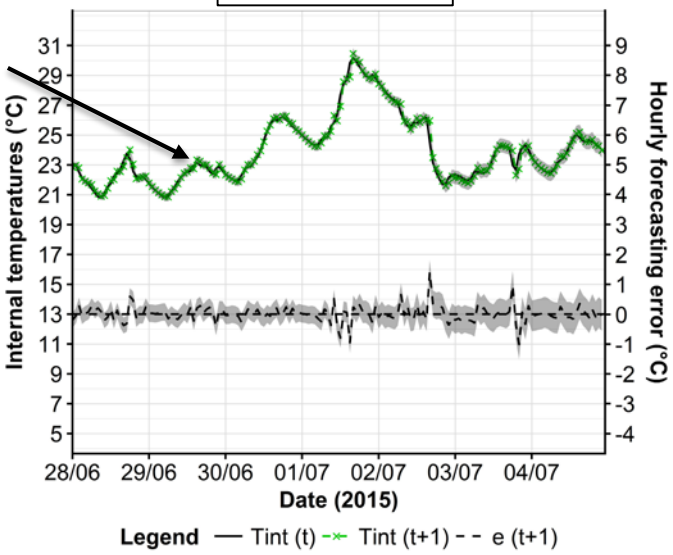
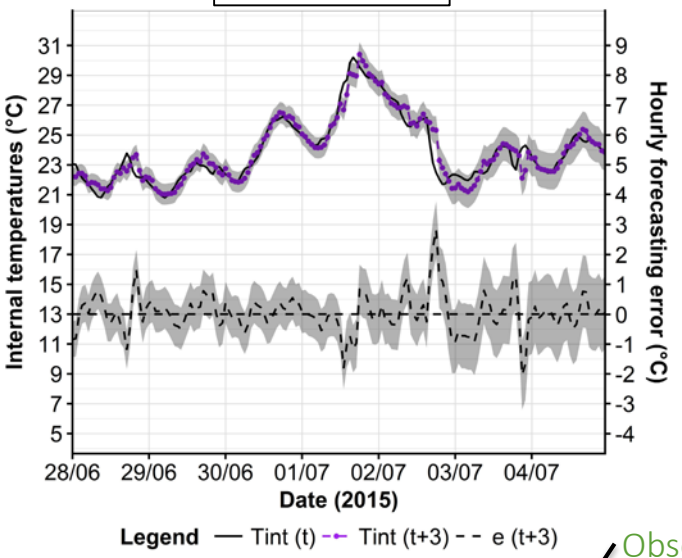
Results - forecasts during the 2015 heatwave

Forecasted temperatures (coloured lines)

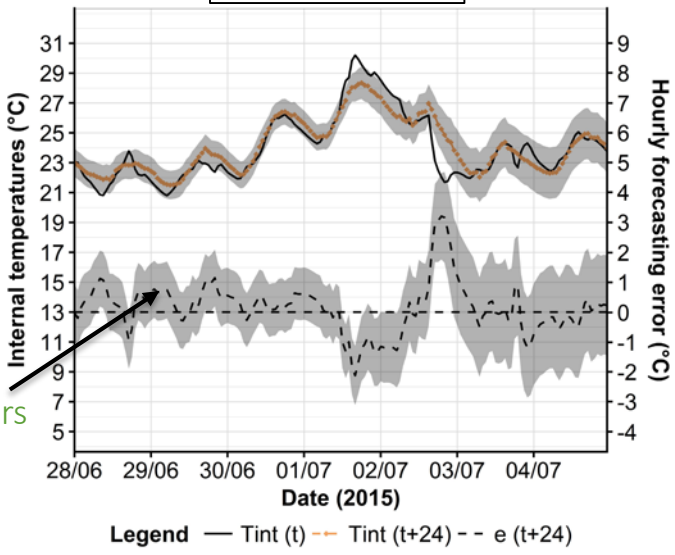
1 h forecasts



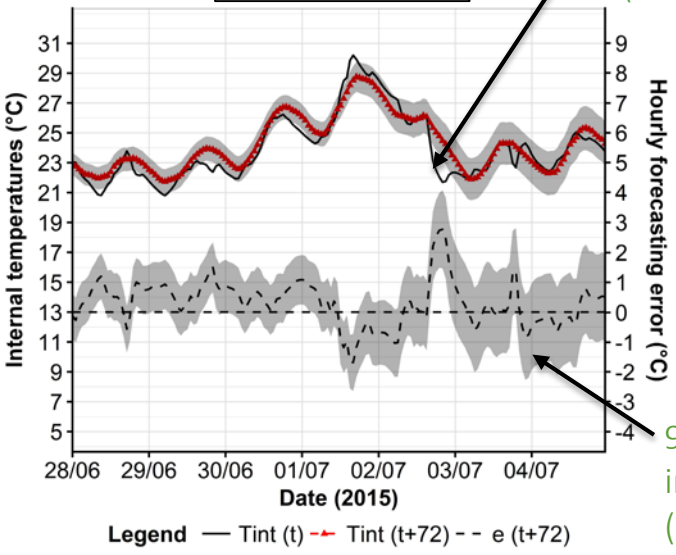
3 h forecasts



24 h forecasts



72 h forecasts



Observed temperatures (black lines lines)

Forecasting errors (dashed lines)

95% prediction intervals (grey shading)

Relevance to policy

HHWS (NOW):

Warnings triggered at regional level (based on outdoor air temperatures)

Issues:

- Cannot identify who is actually at risk of overheating
- Dwellings overheat at different rates during hot weather and some might not even overheat

HHWS (in the FUTURE):

Warnings triggered at local level (i.e. for specific rooms)

Advantages:

- Can identify when, where and who is at a higher risk
- Supply tailored information to occupants on mitigation actions
- Targeted deployment of emergency services

Relevance to industry

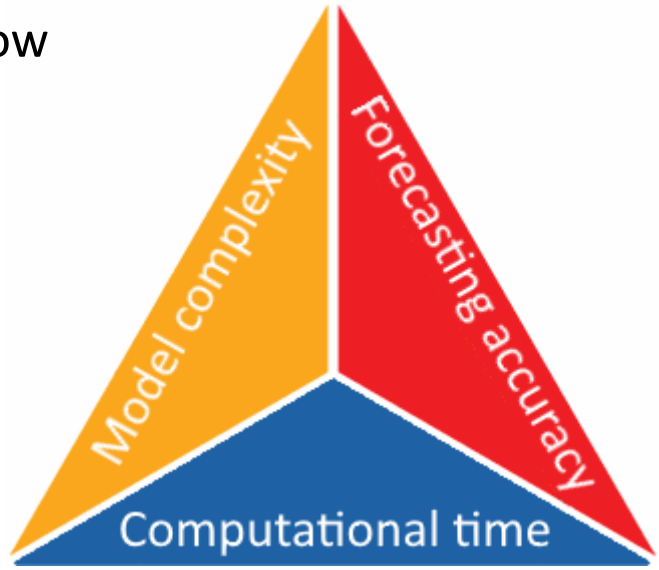
1. EMPIRICAL MODELS CAN BE INTEGRATED IN SIMPLE DEVICES (e.g. SMART METERS)
   - Models can run locally offering on-the-spot temperature predictions

2. CALCULATIONS PERFORMED AT A CENTRALISED DATA CENTRE
   - Readings transferred to data centre via WiFi
   - Occupants receive overheating notifications via smartphones, sms/email; calls from emergency services to vulnerable occupants

Relevance to academia- findings

- More complex models ≠ better forecasts
- Identied why and which models more reliable when forecasting out of the usual range (e.g. heatwaves):
  a) Semi-parametric GAM best for short-term forecasting (≤6h)
  b) Linear ARX models more reliable for longer forecasts, less sensitive and approximate better when predicting out of usual range

- Logistic GAM models adequately predict window opening if established pattern
- Forecasting indoor temperatures with window opening states doesn't improve accuracy



Outputs

- Journal paper (2018)

Building and Environment 143 (2018) 727–739

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Forecasting indoor temperatures during heatwaves using time series models

Matej Gustin[a,b,*], Robert S. McLeod[a,b], Kevin J. Lomas[a,b]

[a] School of Architecture, Building and Civil Engineering, Loughborough University, LE11 3TU, UK
[b] London-Loughborough (LoLo) EPSRC Centre for Doctoral Training in Energy Demand, Loughborough University, LE11 3TU, UK

- ‘Best student paper’ award at the BSO 2018 conference in Cambridge

Proceedings of BSO 2018:
4th Building Simulation and Optimization Conference, Cambridge, UK: 11-12 September 2018

Prediction of Internal Temperatures During Hot Summer Conditions with Time Series Forecasting Models

Matej Gustin[1,2,*], Rob S. McLeod[1,2], Kevin J. Lomas[1,2]

- Journal paper (in development): ‘Can semi-parametric models outperform linear models when occupant interventions are incorporated for the prediction of overheating in dwellings?’

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References

[1] De Bono, A. et al. , 2004. Impacts of summer 2003 heat wave in Europe. Environment Alert Bulletin UNEP (August), p. 4.

[2] Meehl, G.A. and Tebaldi, C. , 2004. More Intense, More Frequent , and Longer Lasting Heat Waves in the 21st Century. Science 305(August), pp. 994–997.

[3] Jenkins, G.J. et al. , 2009. The climate of the UK and recent trends. Met Office Hadley Centre, Exeter, UK.

[4] World Meteorological Organization, 2018. July sees extreme weather with high impacts

[5] Stott , P. et. al., 2004. Human contribution to the European heatwave of 2003. doi:10.1038/nature03089.

[6] World Health Organization , 2009. Improving public health responses to extreme weather/heat-waves: EuroHEAT. WHO Regional Office for Europe , pp. 1–70.

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[8] Chan, N.Y. et al. , 2001. An empirical mechanistic framework for heat-related illness. Climate Research 16(2), pp. 133–143. doi: 10.3354/cr016133.

[9] Mavrogianni, A. et al. , 2010. London housing and climate change: Impact on comfort and health - Preliminary results of a summer overheating study. Open house international journal 35(2), pp. 49–58.

[10] Kenny, G.P. et al. , 2010. Heat stress in older individuals and patients with common chronic diseases. Cmaj 182(10), pp. 1053–1060. doi: 10.1503/cmaj.081050.

[11] Anderson, M. et al. , 2013. Defining indoor heat thresholds for health in the UK. Perspectives in Public Health 133(3), pp. 158–164. doi: 10.1177/1757913912453411.

[12] Met Office , 2016. 10 day weather forecast - Met Office.