INGENIOUS

Understanding Air Pollution in Homes

Thermal comfort, air change rates and levels of particulate matter in 300 homes in Bradford

Lia Chatzidiakou and the INGENIOUS team

University of York

WACL Wolfson Atmospheric Chemistry Laboratories

The University Of Sheffield.

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

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The University of Manchester

bib We are family BORNINBRADFORD

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UKRI Natural Environment Research Council

Met Office

Clean Air Programme

Overview of the INGENIOUS project

Real home assessment survey

Deployment set-up

3 rooms per household

Cellular connectivity, Wi-fi and plug extensions

Participant Expresses Interest
- Researcher calls participant to explain study & assess eligibility

Home Visit 1 (Day 1)
- Researcher obtains informed consent
- Home survey is administered
- Building audit is performed
- AirGradient sensors are installed

Home Visit 2 (Day 10/11)
- VOC canister & PM sampler are installed (sub-sample)

Home Visit 3 (Day 14)
- Health & behaviour questionnaire is administered
- AirGradient sensors, VOC canister & PM sampler are removed
- Qualitative interviews scheduled (sub-sample)

Personalised Feedback
- Participant receives feedback on indoor air pollution
- Participant has opportunities to ask any questions

2-week monitoring (N = 300)
- AirGradient sensors collect data
- Participant completes two diaries

72-hour monitoring (N = 150)
- VOC canister & PM sampler collect data
- Participant completes one diary

Kitchen

Living room

Child's bedroom

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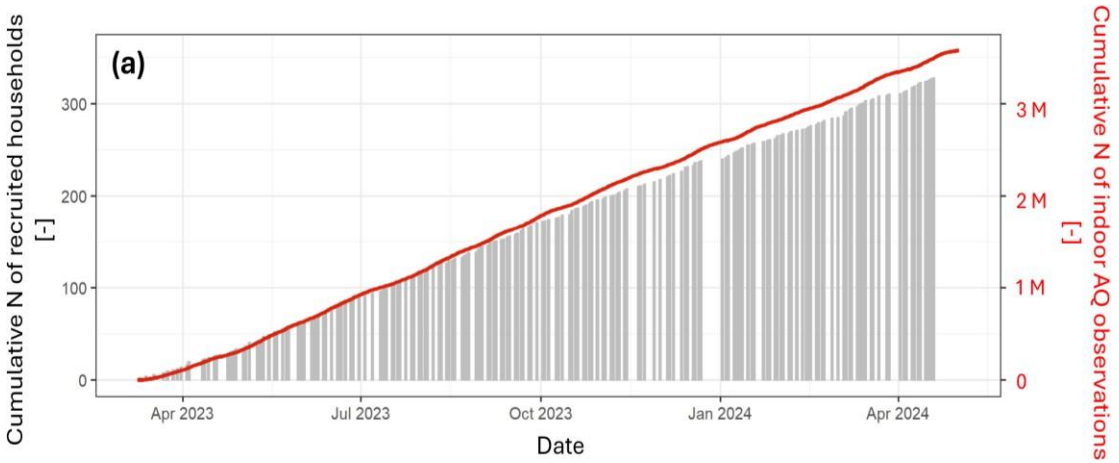
Ikeda E, et al. 2023; doi:10.1136/ bmjopen-2023-081099

Recruitment of households

310 Households corresponding to ~3.5 M observations !



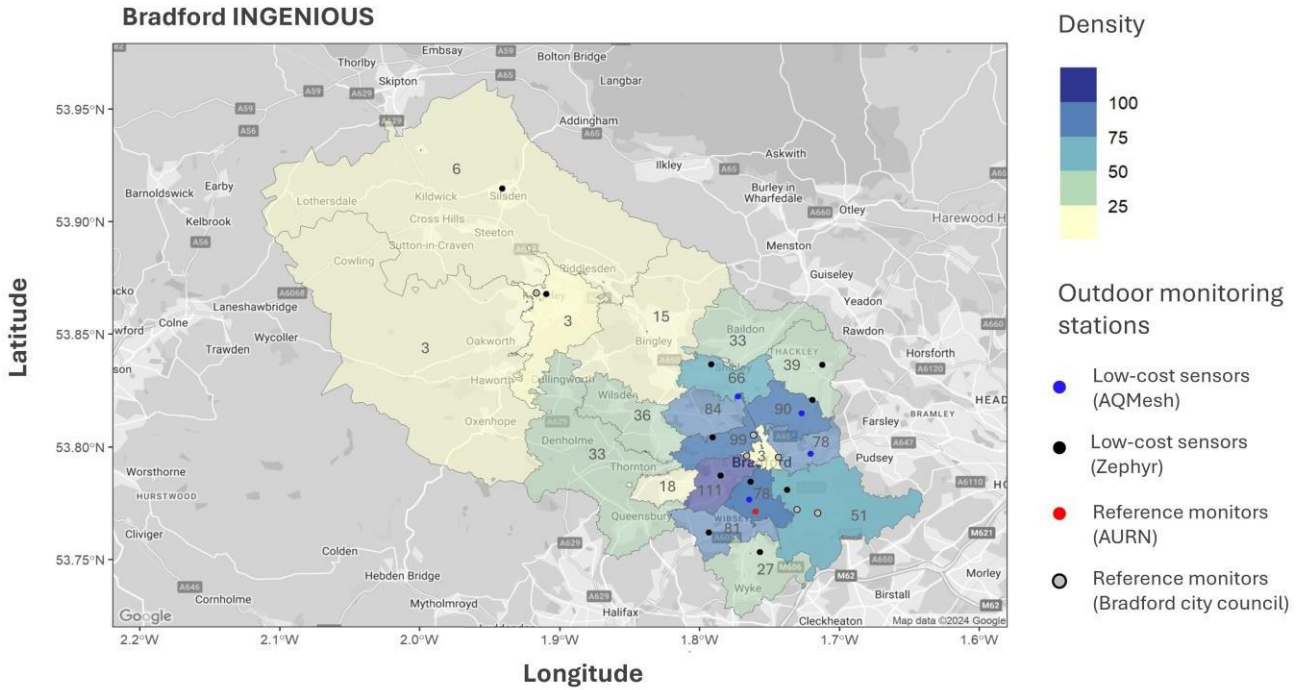
Cumulative number of households and observations collected during the deployment period March 2023- April 2024.

House tenure, childhood asthma, ethnicity

Table 1 The recruitment target of 300 BiB families stratified by child ethnicity, housing tenure and childhood asthma

		Housing tenure			
		Private/mortgaged property (n=210; 70%)		Rented property (n=90, 30%)	
		Asthma (50%)	Non-asthma (50%)	Asthma (50%)	Non-asthma (50%)
Ethnicity	South Asian (n=135; 45%)	n=48; 16.0%	n=47; 15.7%	n=20; 6.7%	n=20; 6.7%
	White British (n=135; 45%)	n=48; 16.0%	n=47; 15.7%	n=20; 6.7%	n=20; 6.7%
	Other (n=30; 10%)	n=10; 3.3%	n=11; 3.7%	n=5; 1.7%	n=4; 1.3%

BiB, Born in Bradford.



Spatial distribution of INGENIOUS households by postcode district and locations of the outdoor monitoring stations of the outdoor sensor network

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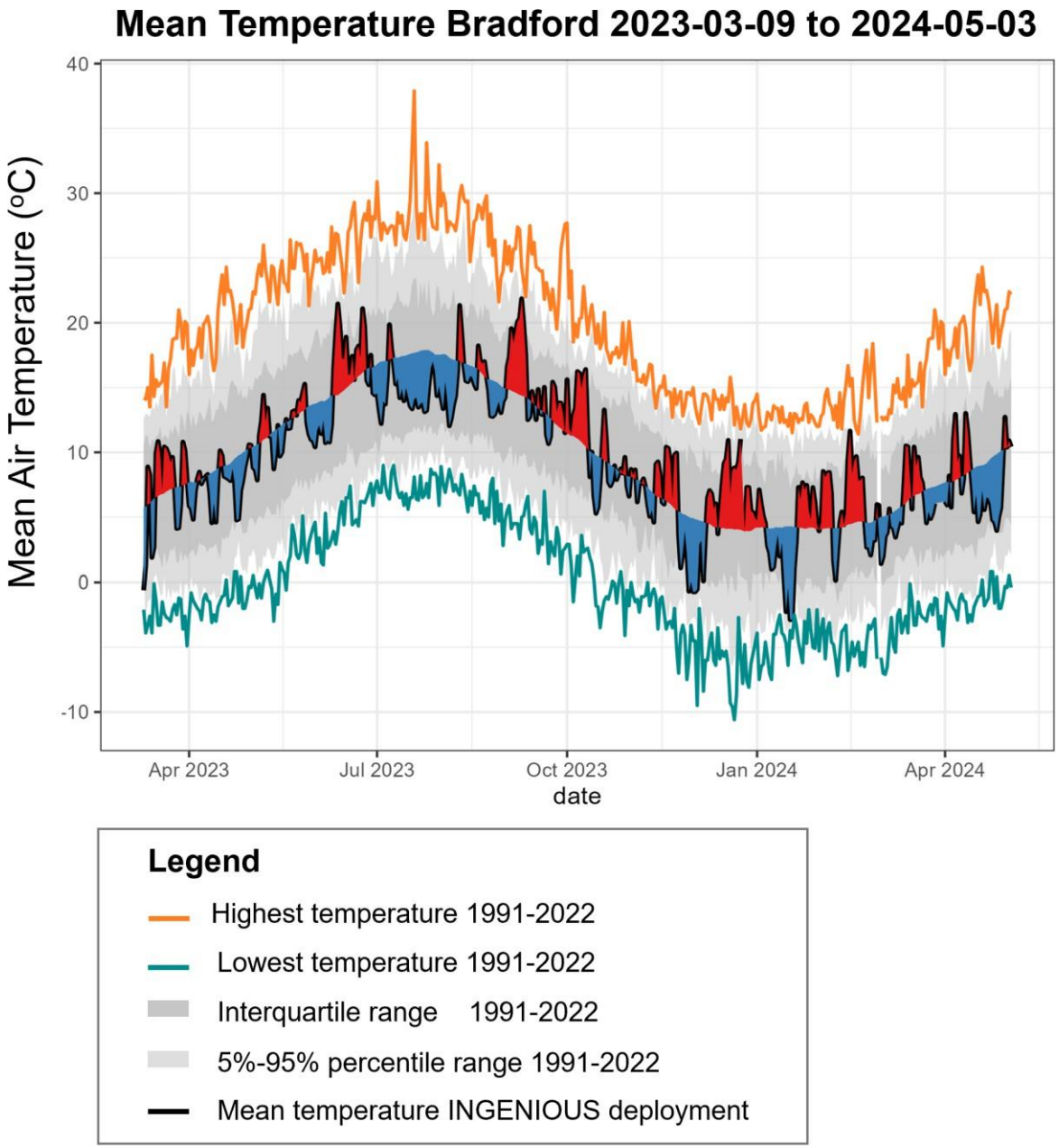


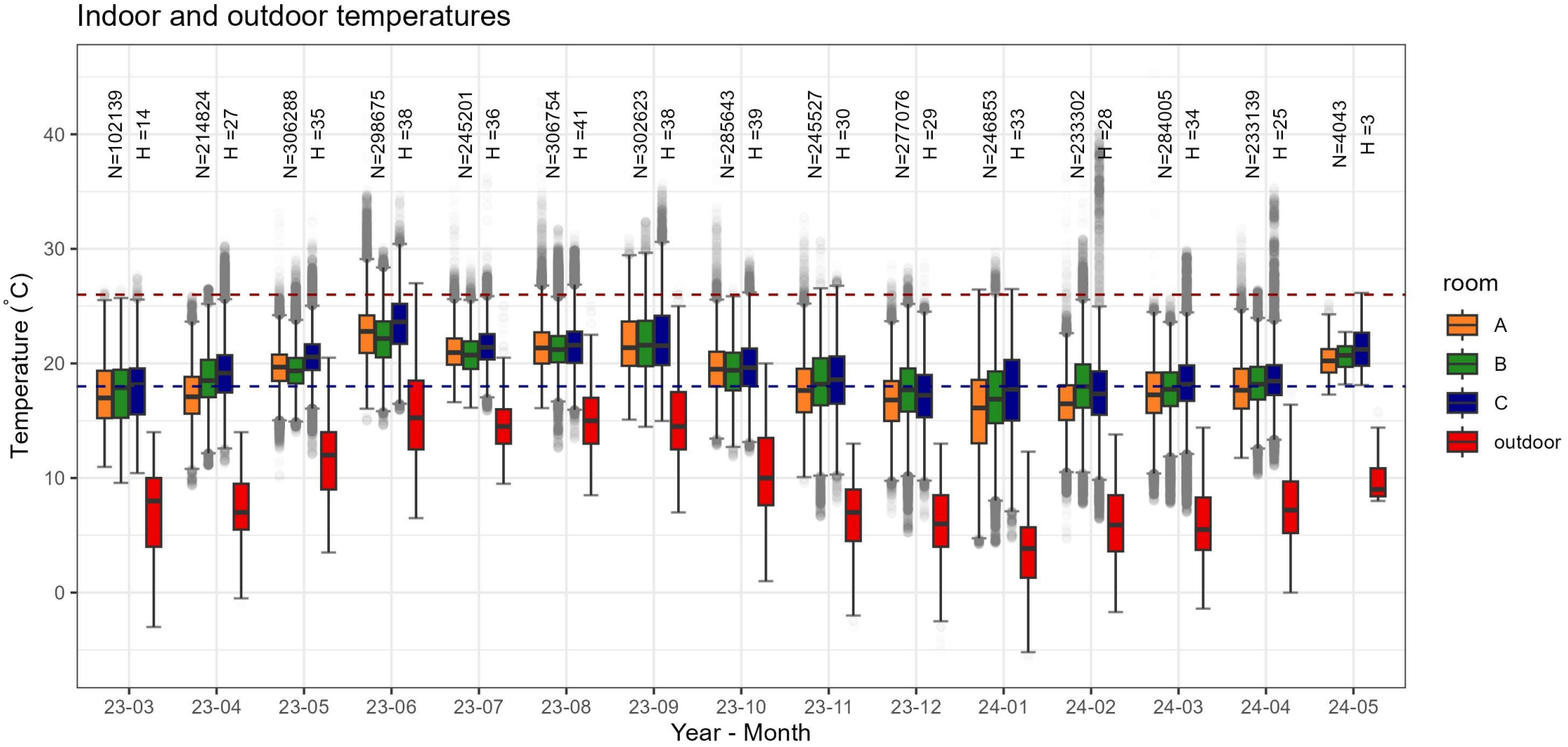
Data downloaded from MIDAS

Deployment period within the range of previous years

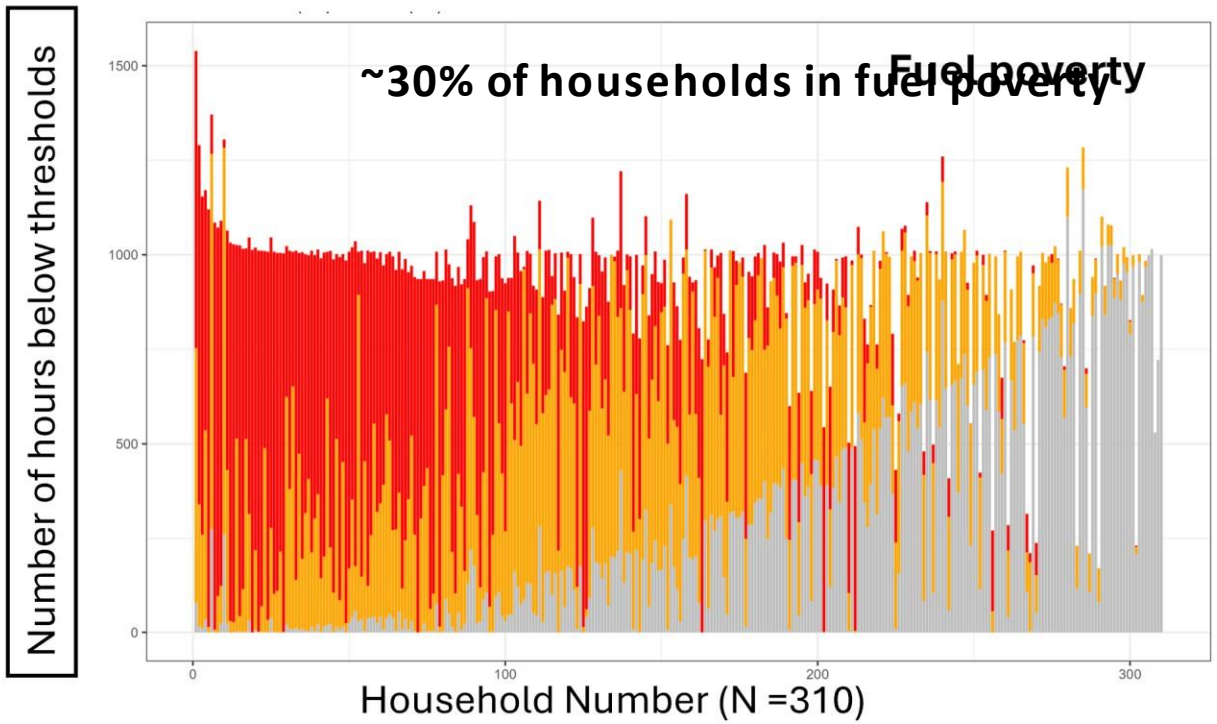
- **Unusually warm September**
- **Cold spells late Nov 2023 – March 2024**

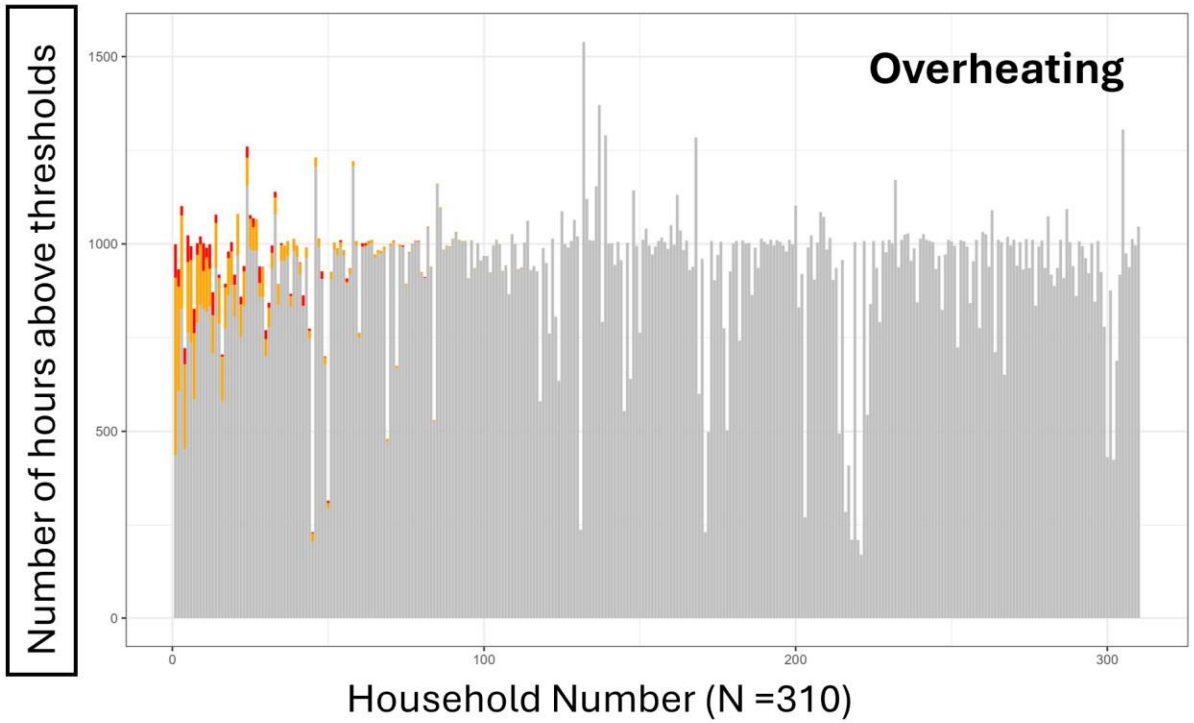
Was 2023-2024 unusual?

Climatologically not a weird year


Indoor and outdoor temperatures
N=102139
H =14
N=214824
H =27
N=306288
H =35
N=298675
H =38
N=245201
H =36
N=306754
H =41
N=302623
H =38
N=285643
H =39
N=245527
H =30
N=277076
H =29
N=246853
H =33
N=233302
H =28
N=284005
H =34
N=233139
H =25
N=4043
H =3
Temperature (°C)
40
30
20
10
0
23-03
23-04
23-05
23-06
23-07
23-08
23-09
23-10
23-11
23-12
24-01
24-02
24-03
24-04
24-05
Year - Month
room
A
B
C
outdoor

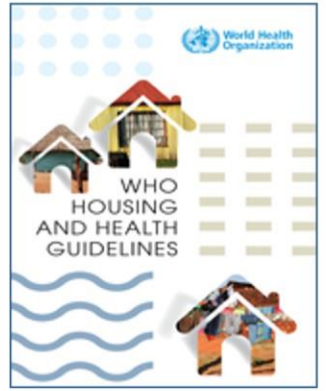
Thermal comfort – thresholds





With these thresholds underheating is quite common and may have significant health implications

And overheating .....



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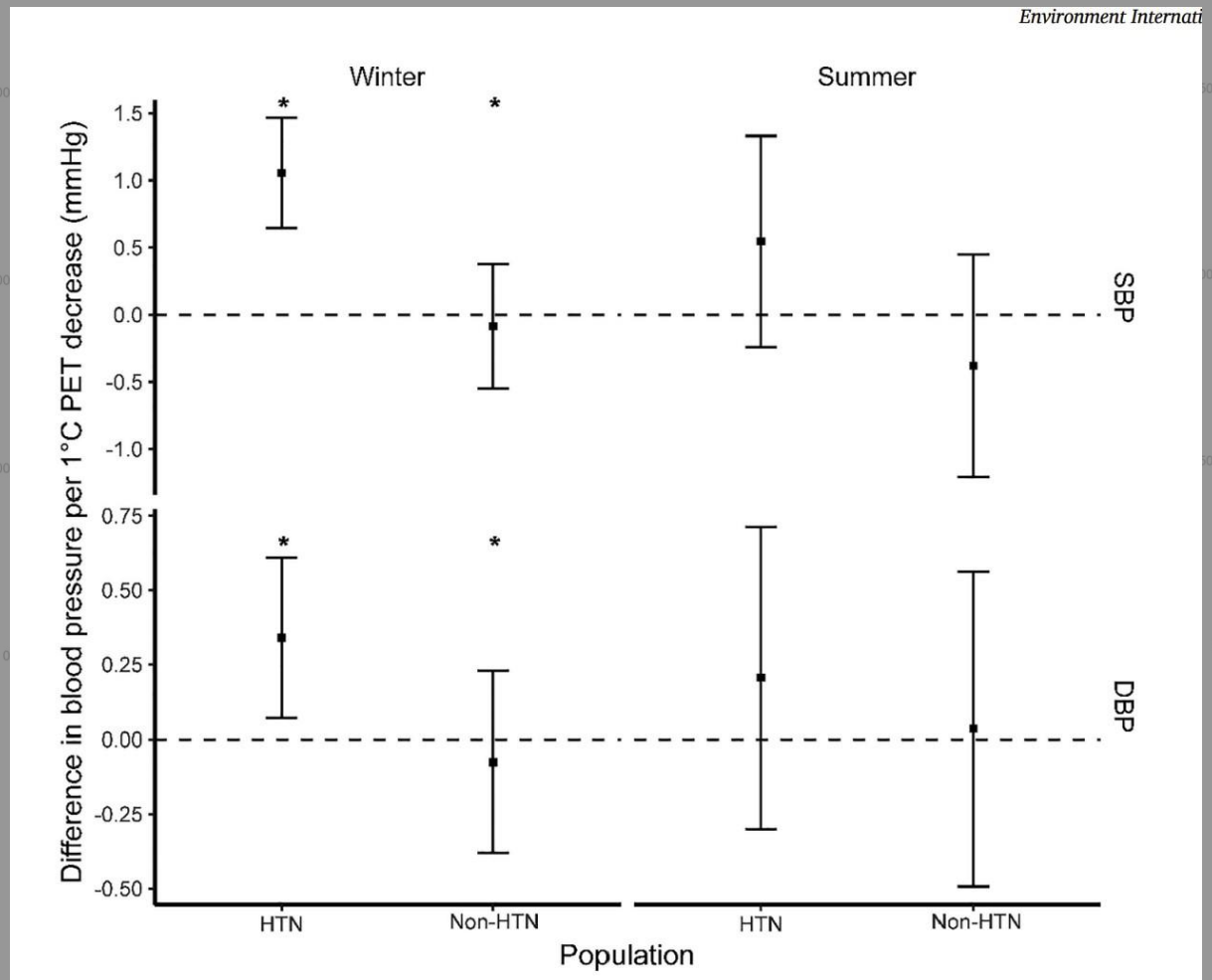
Thermal comfort – thresholds



Estimated differences in Systolic (SBP) and diastolic blood pressure (DBP) of individuals with and without hypertension per 1 ^{o}C decrease in average personal environmental temperature over 24 h before the clinical visits in winter and summer (results from the AIRLESS project with 250 participants)

Number of hours below thresholds

Overheating

Hours above 28 ^{o}C

Considering the high prevalence of hypertension in the UK, I expect similar results !

Environment International
Volume 185, March 2024, 108567

Full length article

Susceptibility of hypertensive individuals to acute blood pressure increases in response to personal-level environmental temperature decrease

Yifan Xu [a 1], Yiqun Han [a b 1], Wu Chen [a], Lia Chatzidiakou [c], Li Yan [b], Anika Krause [c], Yilin Li [c], Hanbin Zhang [b], Teng Wang [a], Tao Xue [d], Queenie Chan [b], Ben Barratt [b], Roderic L. Jones [c], Jing Liu [e], Yangfeng Wu [f], Meiping Zhao [g], Junfeng Zhang [h], Frank J. Kelly [b], Tong Zhu [a]

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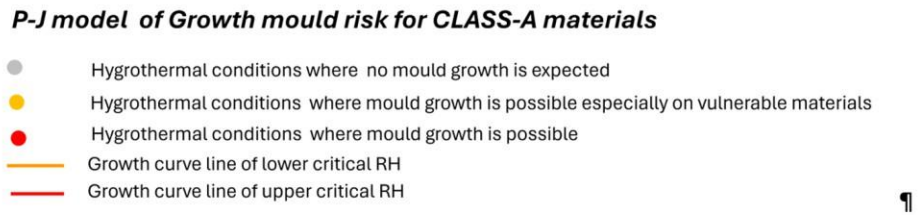
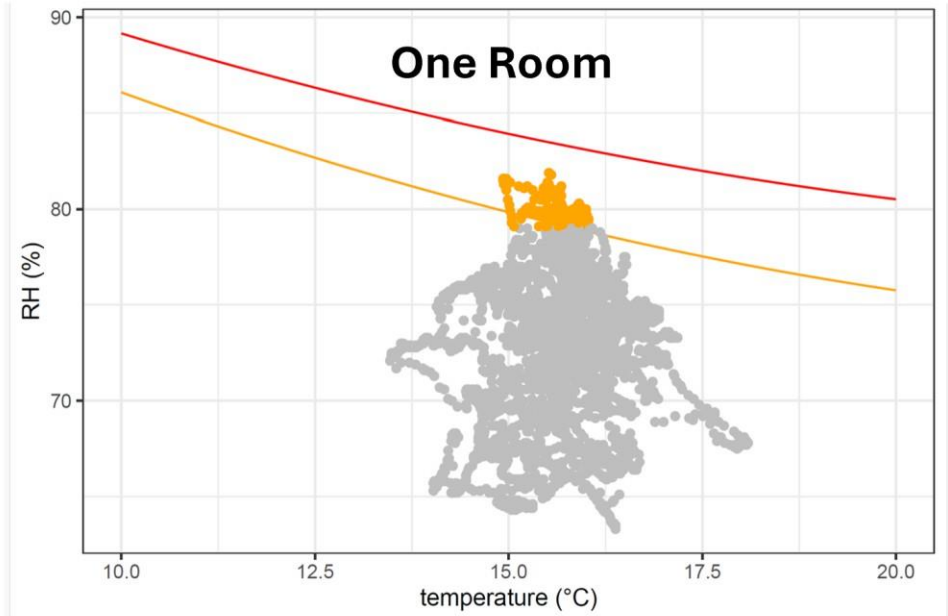
Hygrothermal conditions: Mould growth risk

Semi-quantitative mould assessment (visual and olfactory observation) is considered as reliable as quantitative methods

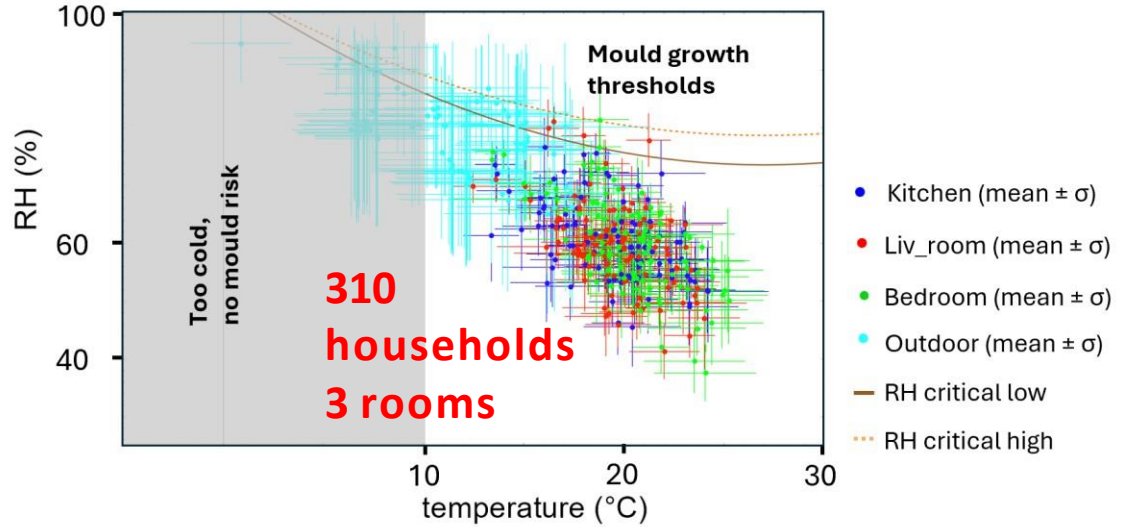
A simple framework to assess health risks



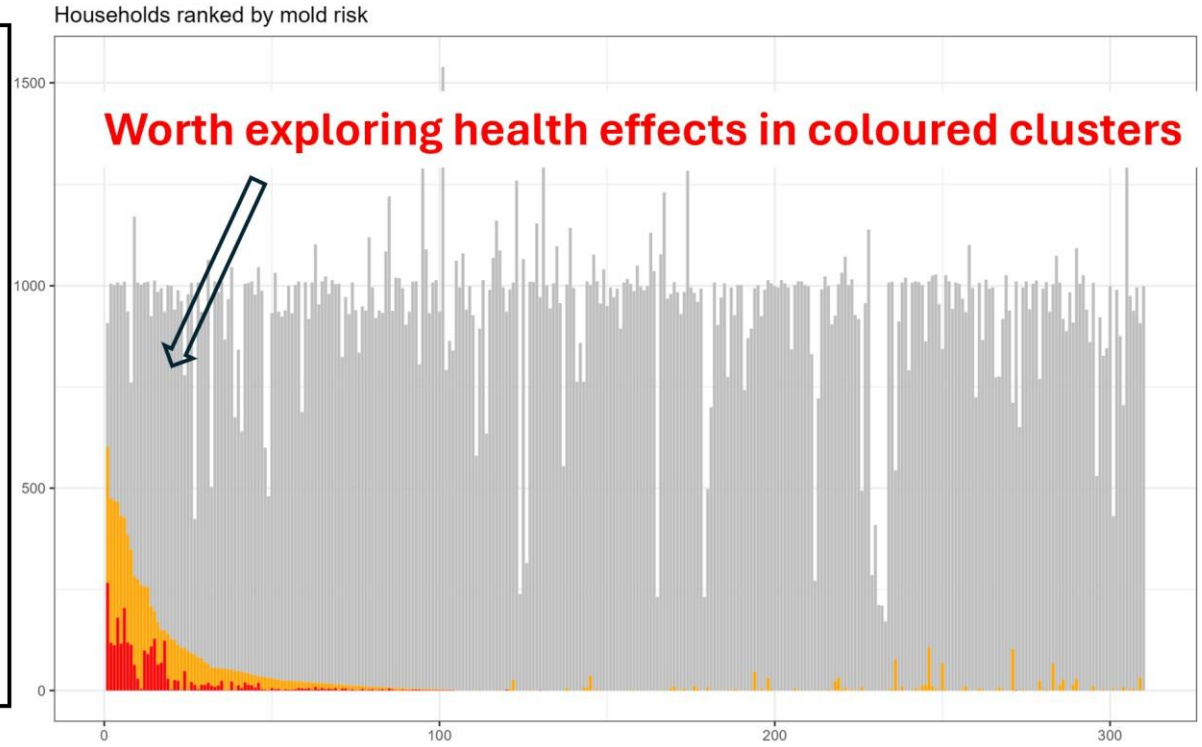


Example of one room where occupant complained of visible mould and severe respiratory symptoms

Indoor hygrothermal conditions (310 households)



Number of hours above thresholds (Hourly averages)



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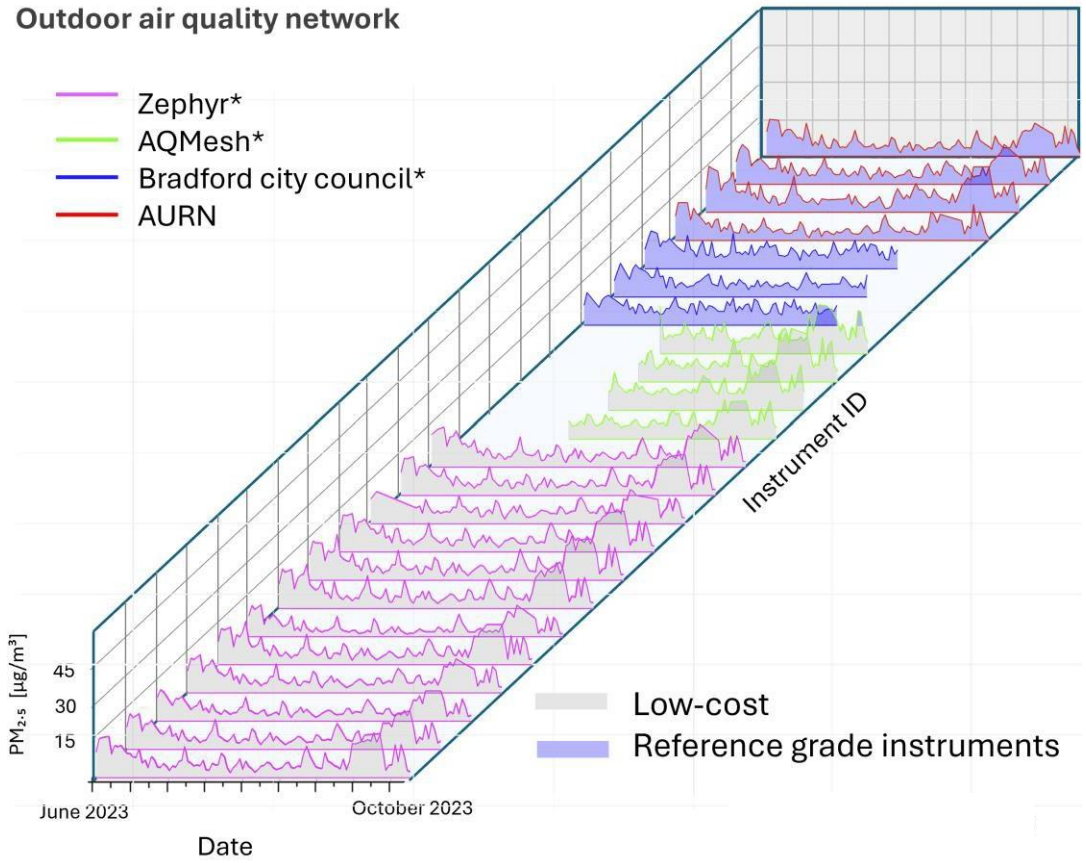
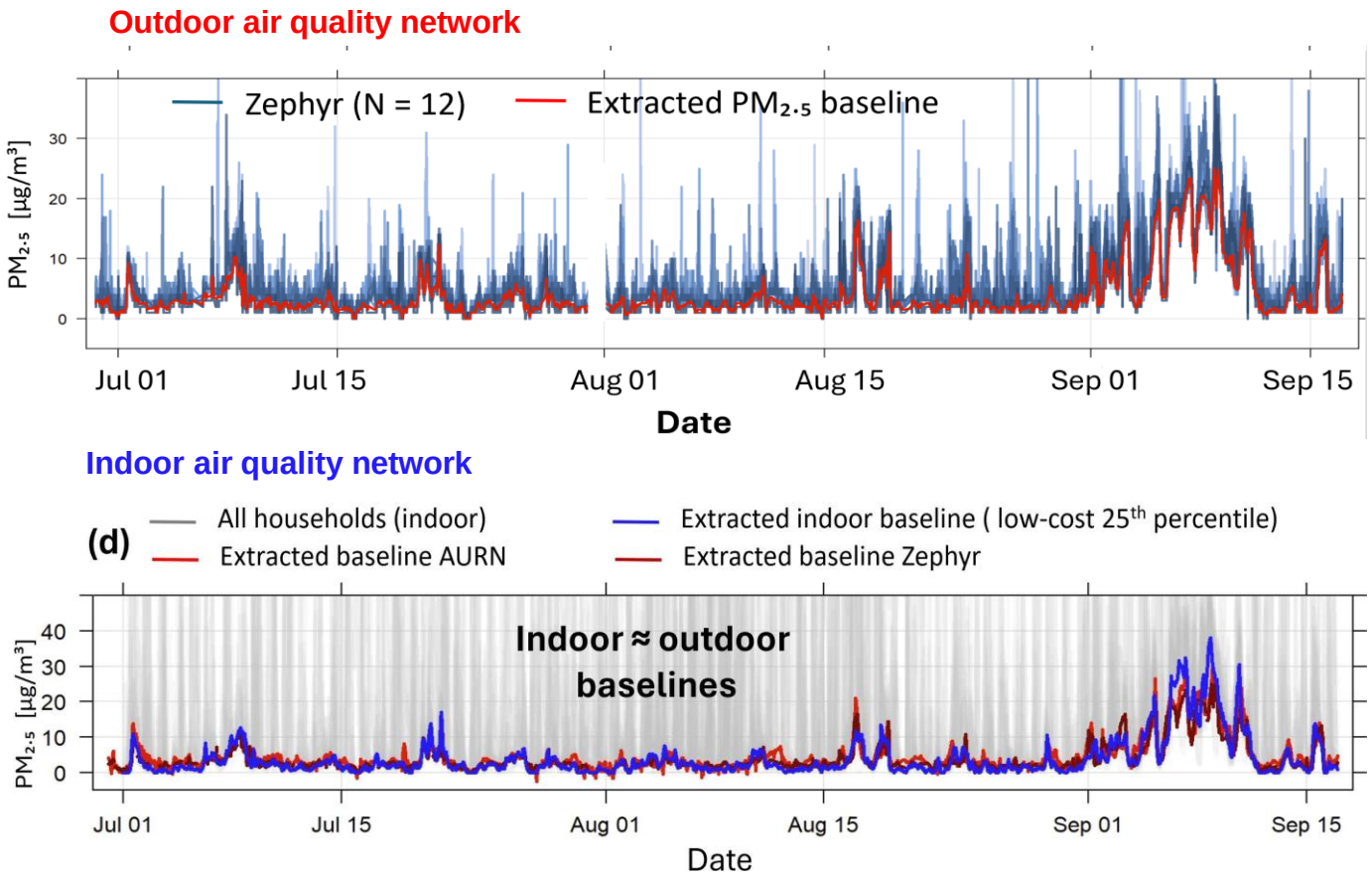
Outdoor air pollution levels (PM)





Outdoor PM levels are dominated by long-range transport

Indoor-generated PM component dominates total household exposure !

BUT outdoor-generated PM is clearly evident indoors (Relative toxicity? Policy?)

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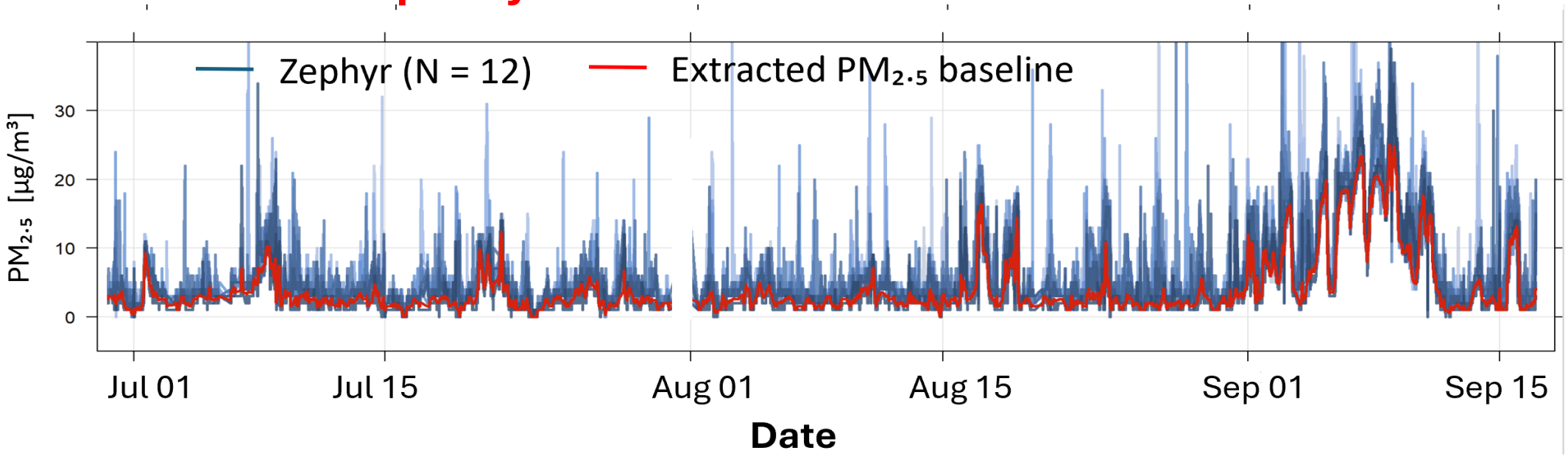
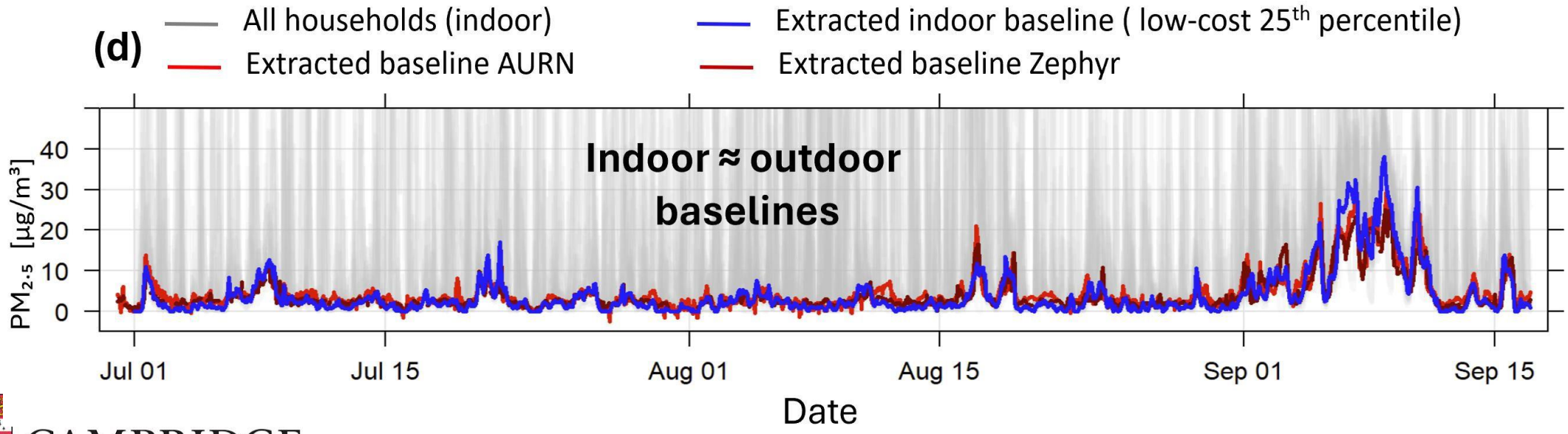
Outdoor air quality network



Indoor air quality network



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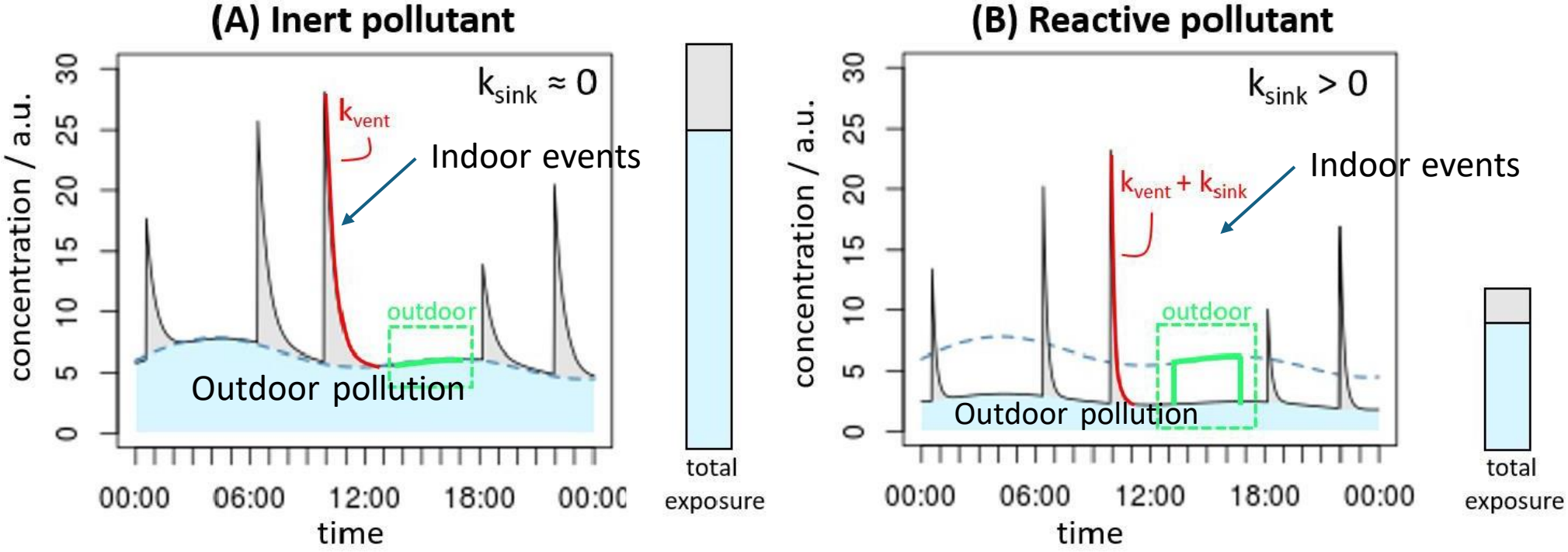
Conceptual model: Understanding air changes, sources and loss rate coefficients



indoor concentration outdoor concentration

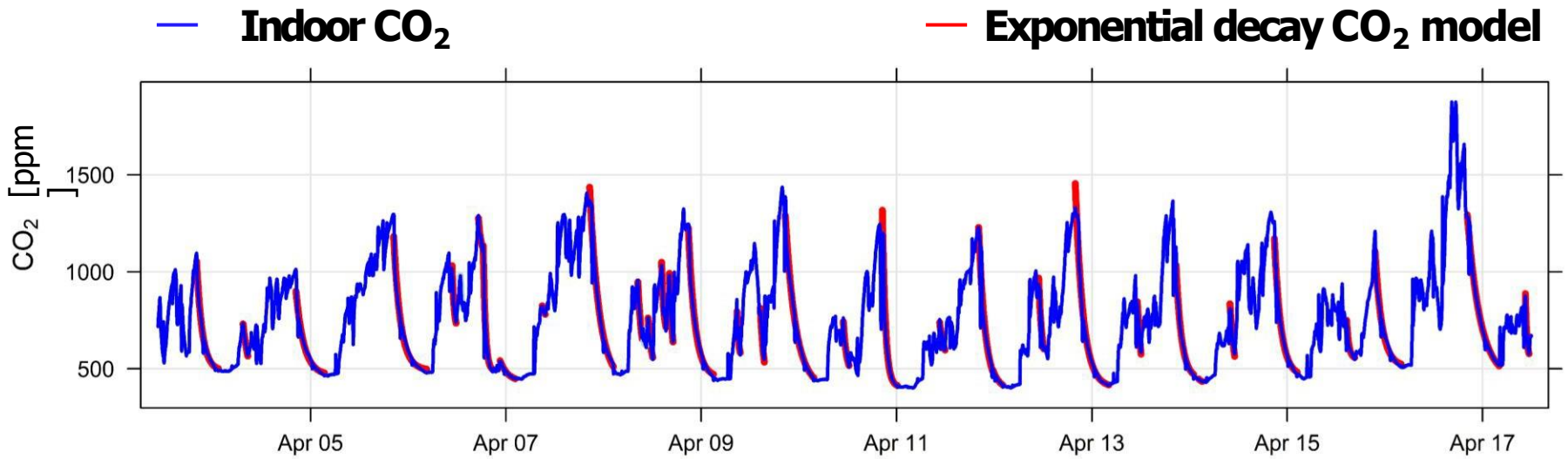
Indoor-generated exposure

Outdoor-generated exposure

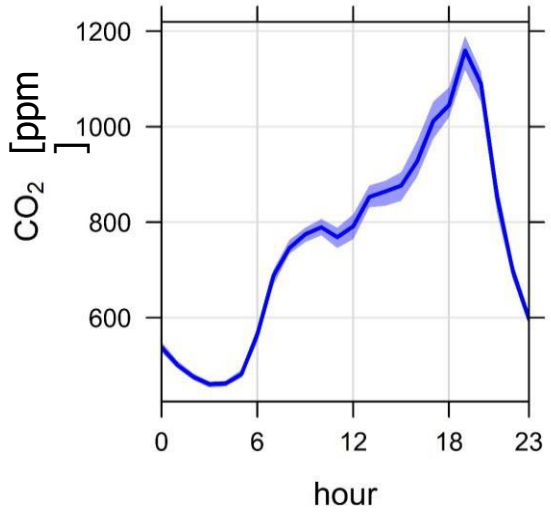
$$\frac{dc_{in}}{dt} = (c_{out} - c_{in})\,k_{vent} - c_{in}\,k_{sink} + S_{indoor}$$

c_{out}, c_{in}	pollutant concentration outdoors and indoors (ppb)
k_{vent}	rate coefficient of building ventilation ($hour^{-1}$)
k_{sink}	rate coefficient of indoor losses (pollution sinks) ($hour^{-1}$)
S_{indoor}	emissions from indoor air pollution sources ($ppb\,hour^{-1}$)

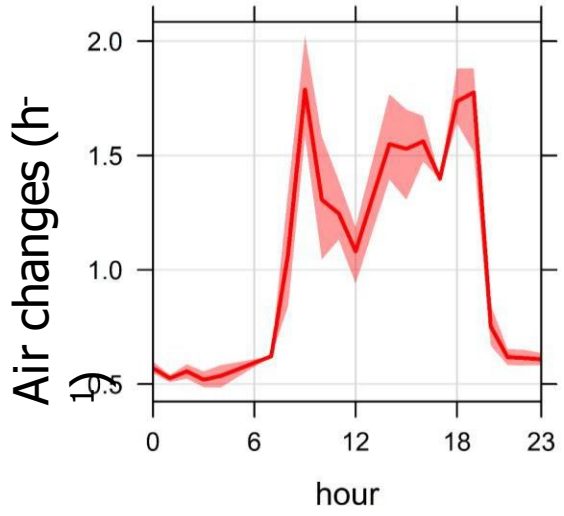
Automated estimation of air changes using CO_2 as a tracer gas



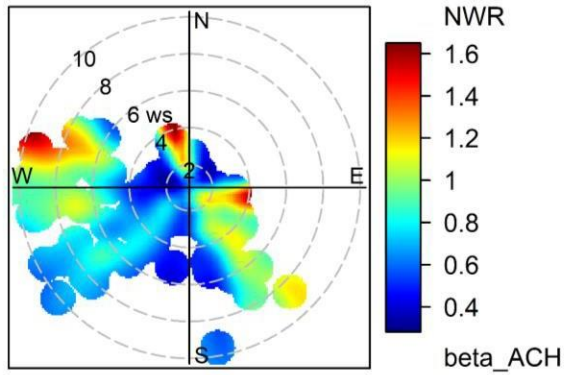
Diurnal pattern CO_2



Diurnal pattern ACH

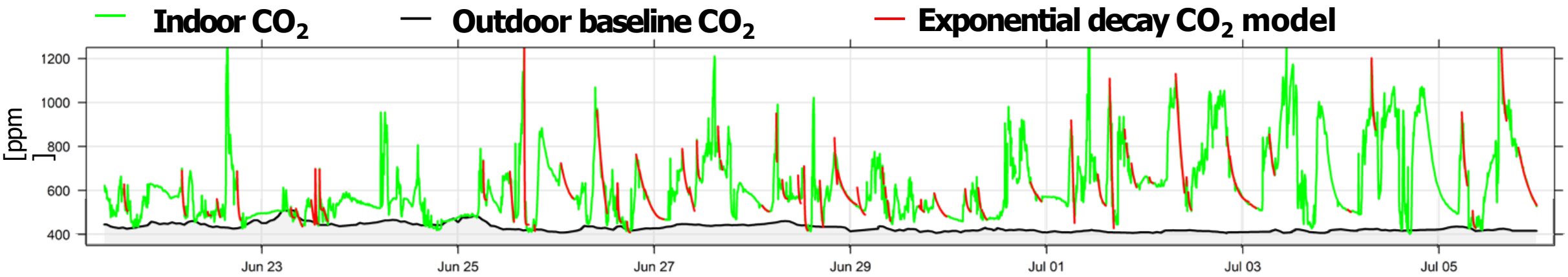


Polar plot ACH

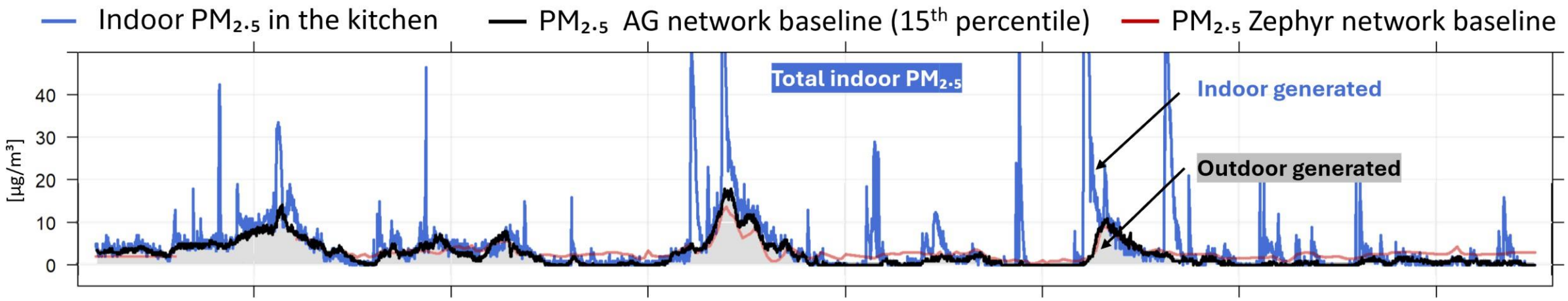


Case study participant (kitchen)

Automated estimation of air changes using CO_2 as a tracer gas



Outdoor and indoor-generated component of PM



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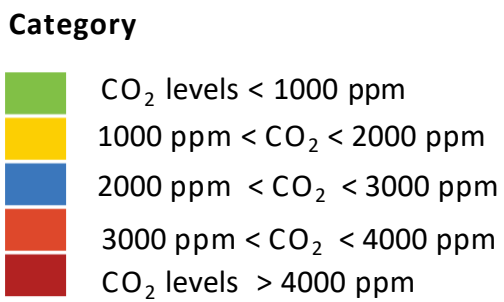
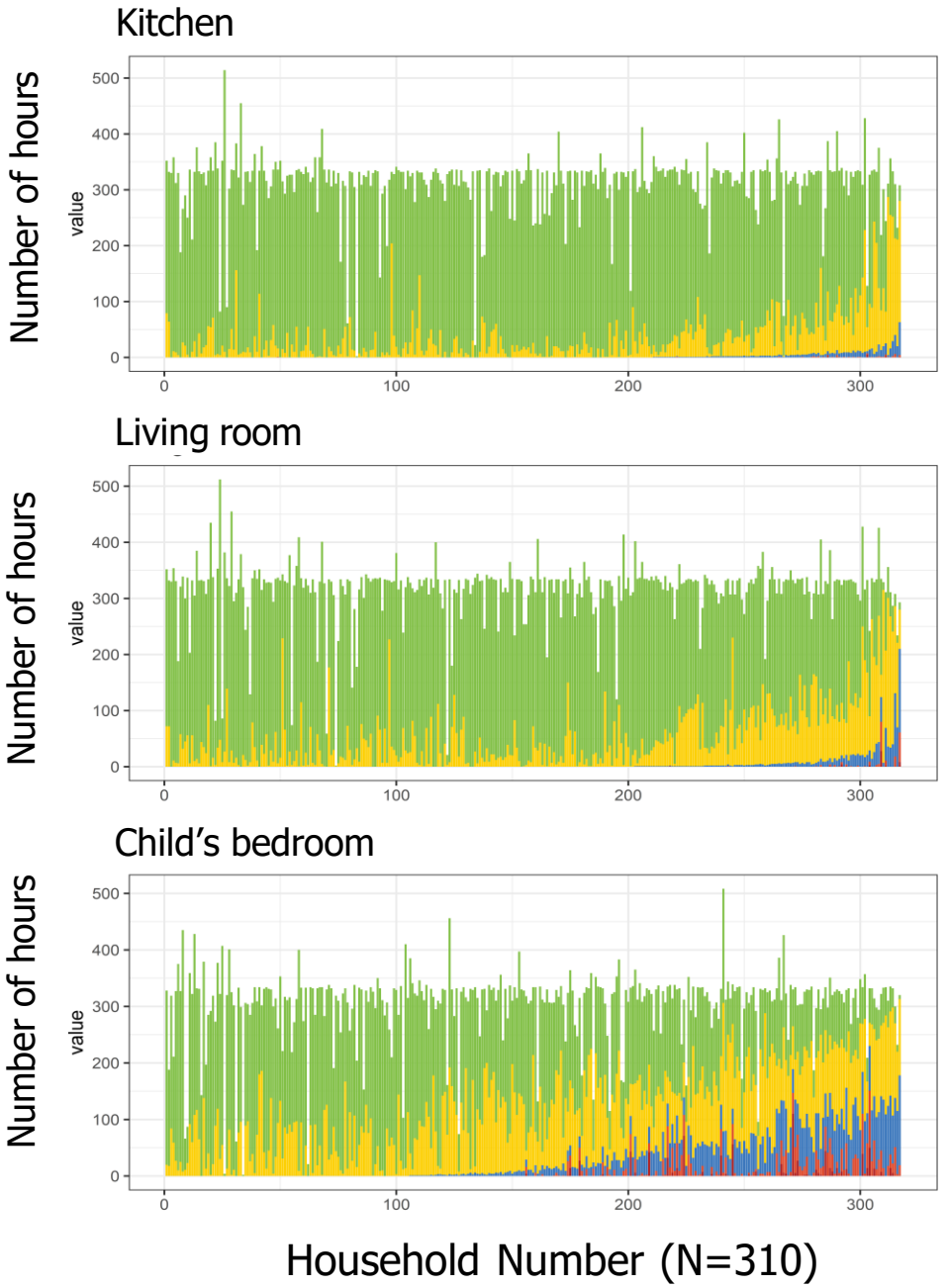
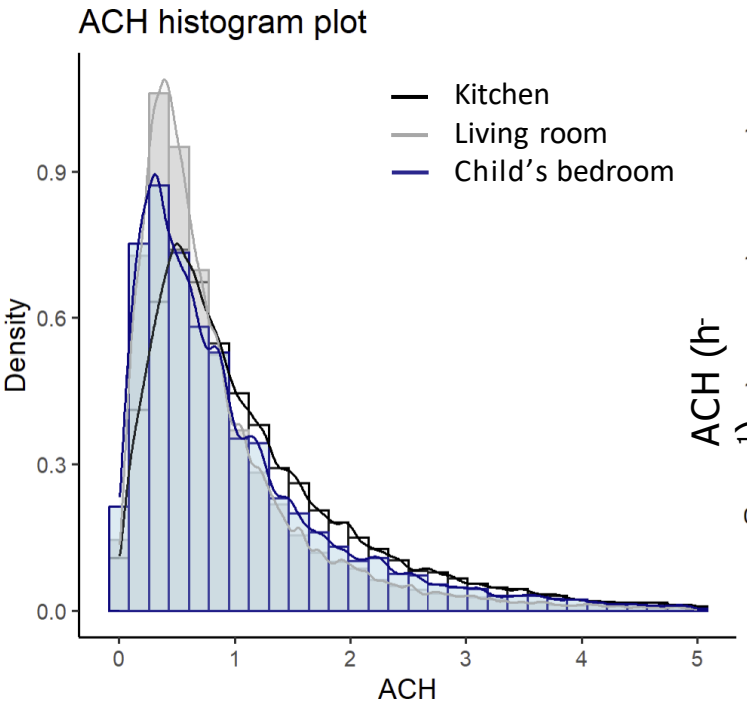
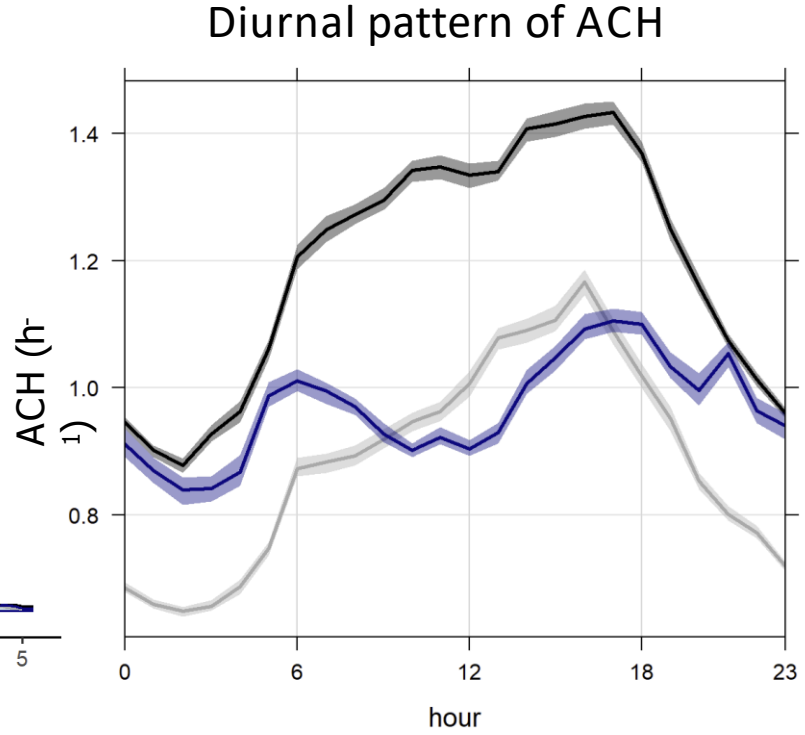
Carbon dioxide and air change rates per hour (ACH): All households





Highest ventilation rates in kitchens





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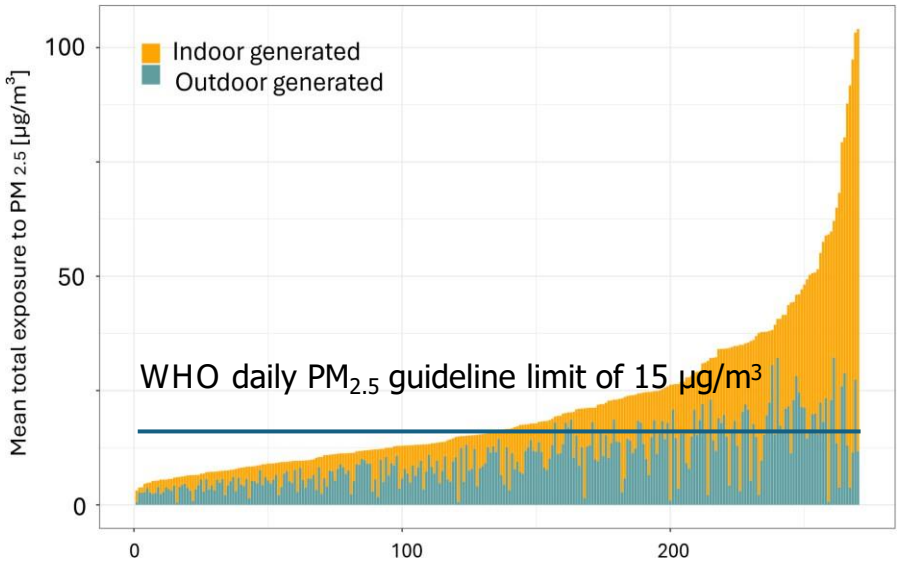
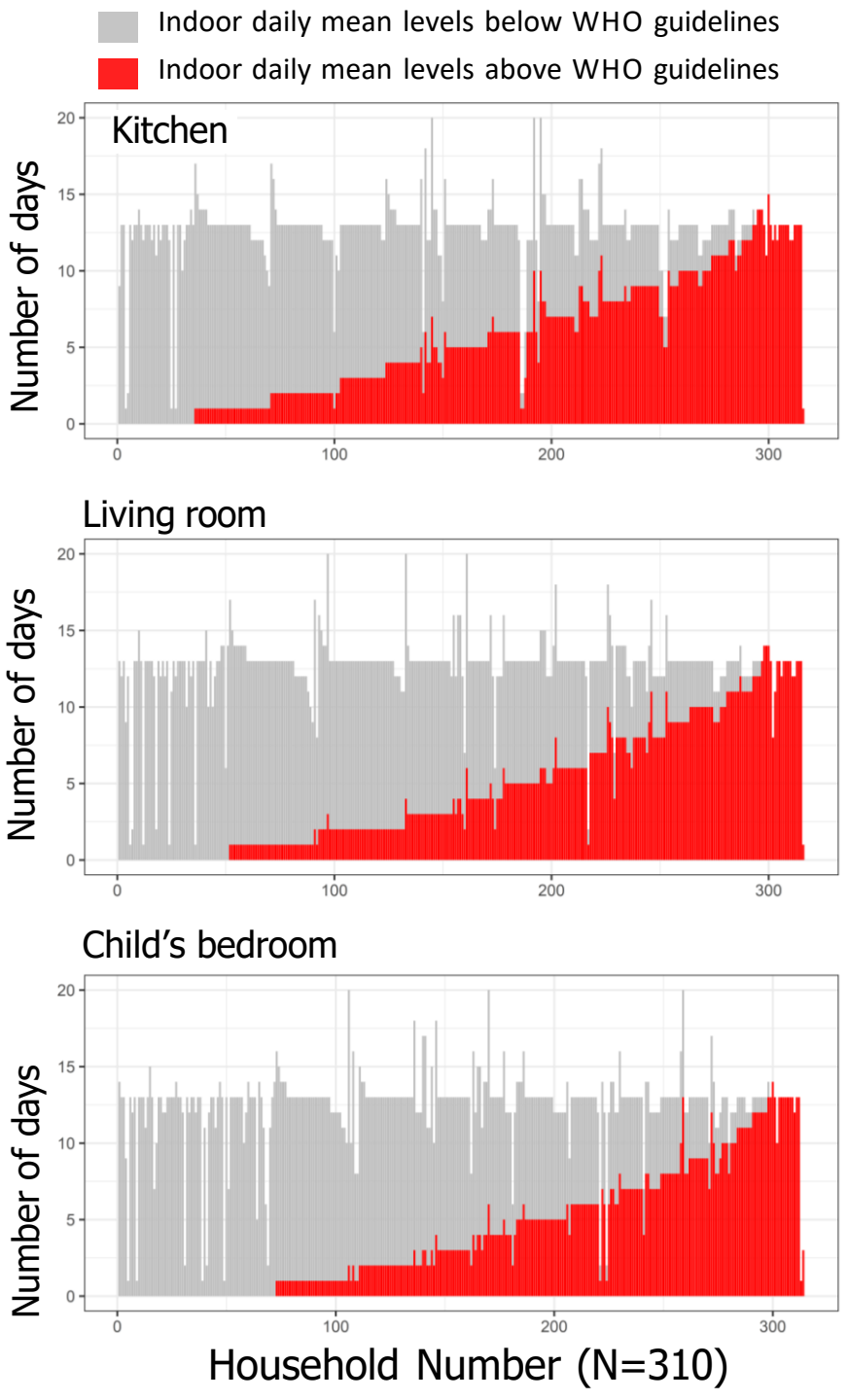
Highest CO_2 levels in children's bedrooms

Indoor and outdoor particulate matter (PM)



The total exposure of each INGENIOUS household has been disaggregated to indoor- and outdoor generated sources (average per household over 2-weeks).

- Indoor-generated exposure varies significantly between participants.
- Outdoor-generated PM is a significant component of exposure for all participants.
- Over 50% of households exceed WHO daily $PM_{2.5}$ guideline limit of 15 µg/m³



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Summary

- Significant percentage of households in **fuel poverty** (evaluated with static criteria)
- Overheating may be an emergent problem as we make houses more airtight
- Analytical techniques can be used to **maximise information content** of measurements (i.e. ventilation rates, loss rate coefficients and indoor emission rates for modelling work etc.);
- Households are significant exposure sites to PM as concentrations often **exceed recommended WHO guidelines** due to significant contribution from both indoor and outdoor sources;
- **Indoor- and outdoor-generated PM** have distinct chemical composition (and therefore potential toxicities);
- **Health impacts from indoor PM currently unknown** and cannot be referenced against outdoor, epidemiologically-derived WHO PM recommendations;

Novel network methodologies developed are a powerful tool to understand **sources** of air pollution, their **health effects** and to guide targeted **interventions/policy recommendations.**

Who we are

Professor **Nicola Carslaw** is the Principal Investigator. **Data collection team:** **Dagmar Waiblinger**, Salma Chopdat.
Early career researchers: Lia Chatzidiakou, Rachael W Cheung, David R Shaw, Simon P. O'Meara, Ashish Kumar, Denisa Genes, Sari Budisulistiorini, Tom Warburton, Yunqi Shao, Athina Ruangkanit. **Co-Is:** David Carslaw, Terry Dillon, Pete Edwards, Chiara Giorio, Jacqui Hamilton, Roderic L Jones, James Lee, Ally Lewis, Rosemary McEachan, Gordon McFiggans, Nicholas Pleace, Sarah West, Chantelle Wood

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Project partners

Universities