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

Lia Chatzidiakou and the INGENIOUS team

2 October 2024, Birmingham

INGENIOUS
Understanding Air Pollution in Homes

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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2024 CONFERENCE
ANALYSIS AND SOLUTIONS:
RESPONDING TO THE CLEAN AIR CHALLENGE

University of Cambridge
UKRI Natural Environment Research Council
Met Office
Clean Air Programme

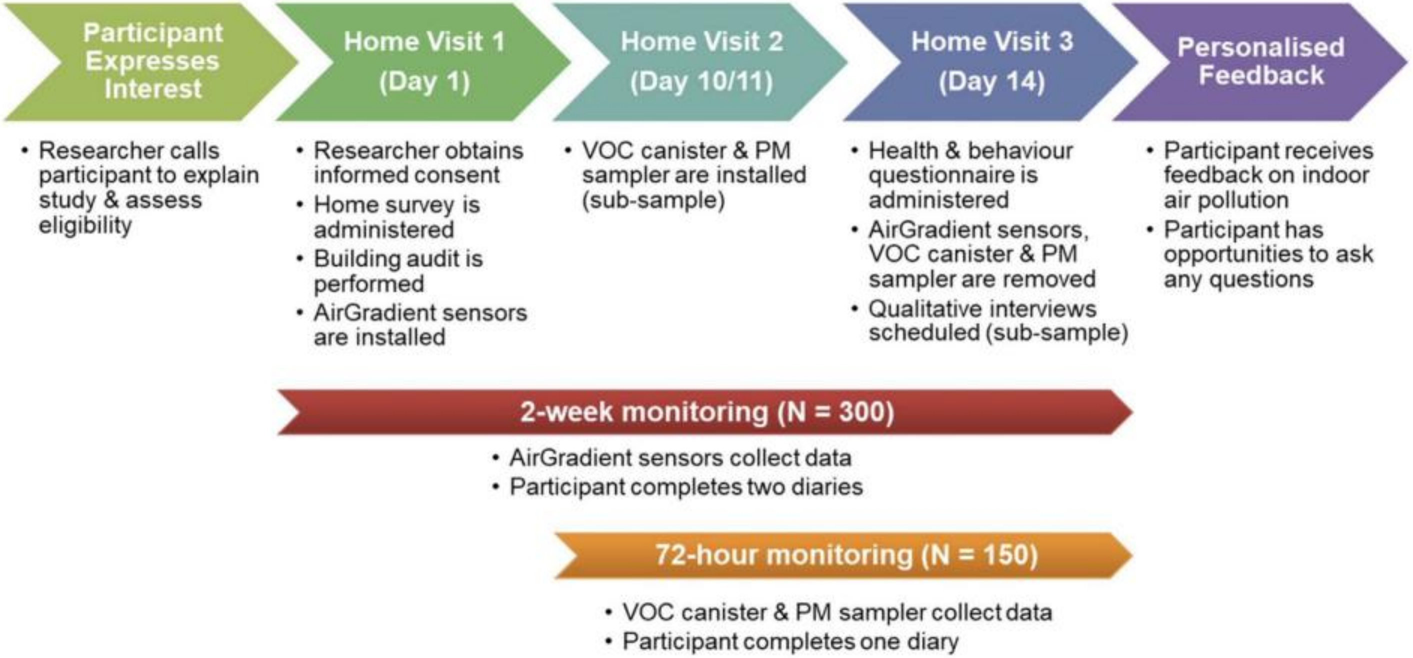
Overview of the INGENIOUS project

Real home assessment survey

Deployment set-up

3 rooms per household

Cellular connectivity, Wi-fi and plug extensions



Kitchen

Living room

Child's bedroom

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

Recruitment of households

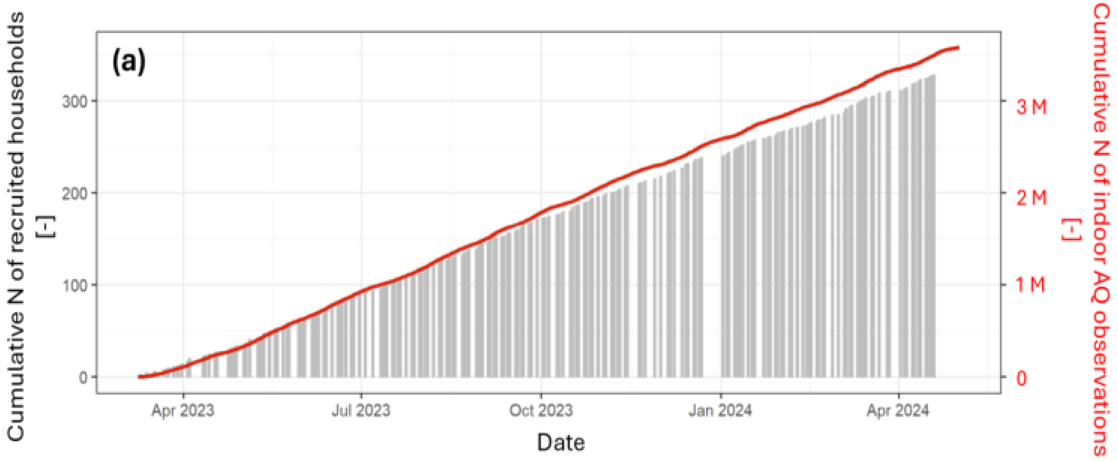
House tenure, childhood asthma, ethnicity

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

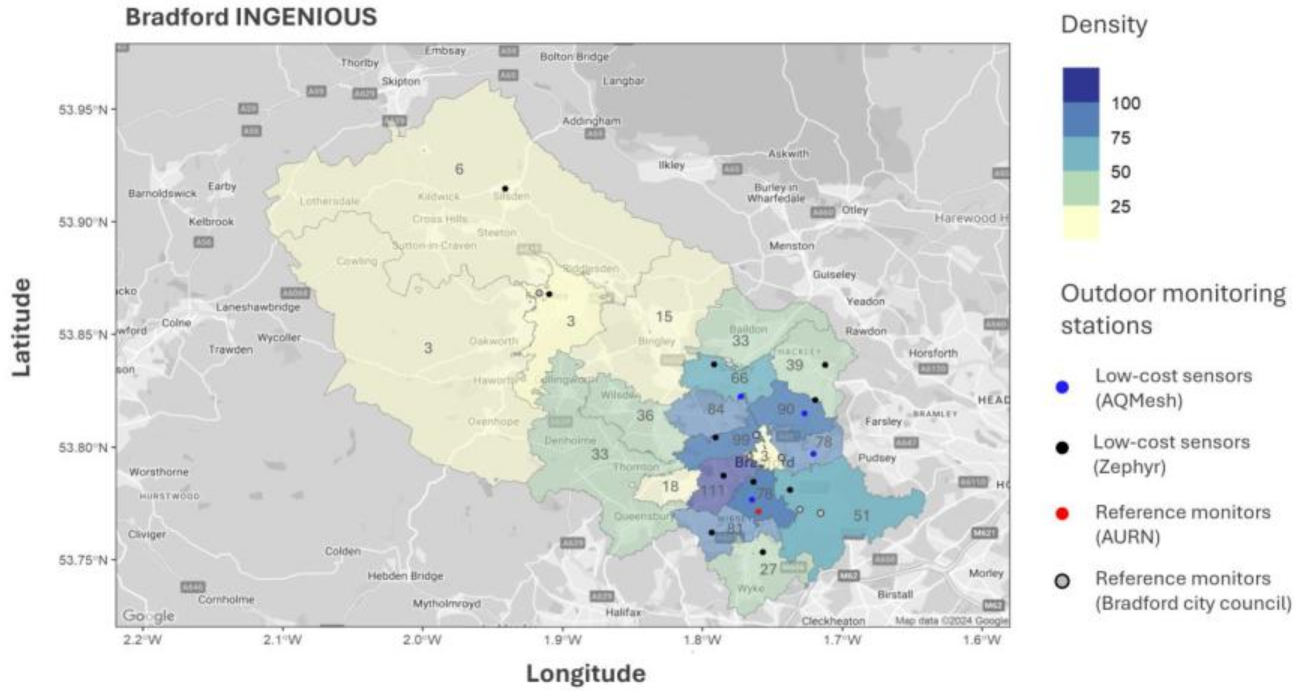
		Housing tenure			
		Private/mortgaged property (n=210; 70%)		Rented property (n=90, 30%)	
		Asthma (50%)	Non-asthma (50%)	Asthma (50%)	Non-asthma (50%)
Ethnicity	South Asian (n=135; 45%)	n=48; 16.0%	n=47; 15.7%	n=20; 6.7%	n=20; 6.7%
	White British (n=135; 45%)	n=48; 16.0%	n=47; 15.7%	n=20; 6.7%	n=20; 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.

310 Households corresponding to ~3.5 M observations !

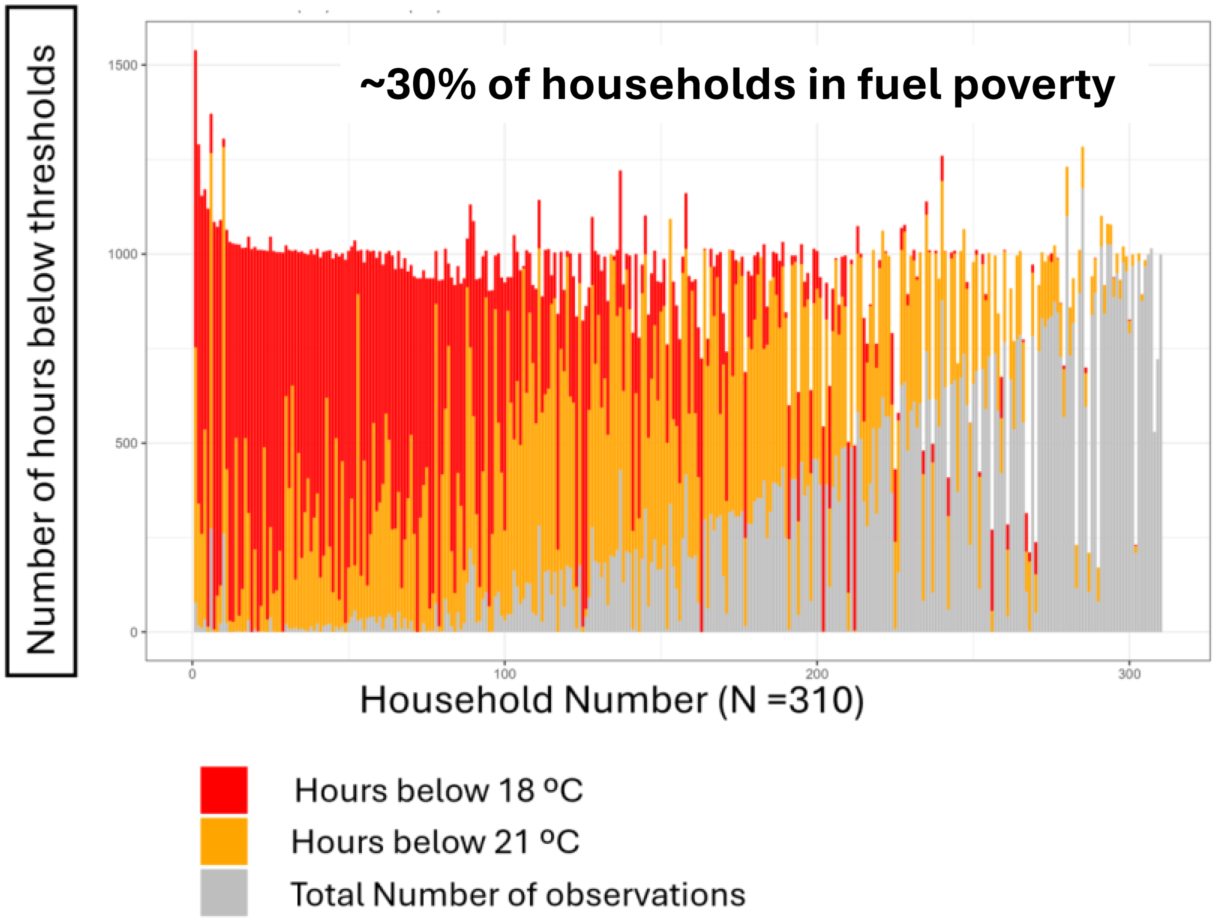


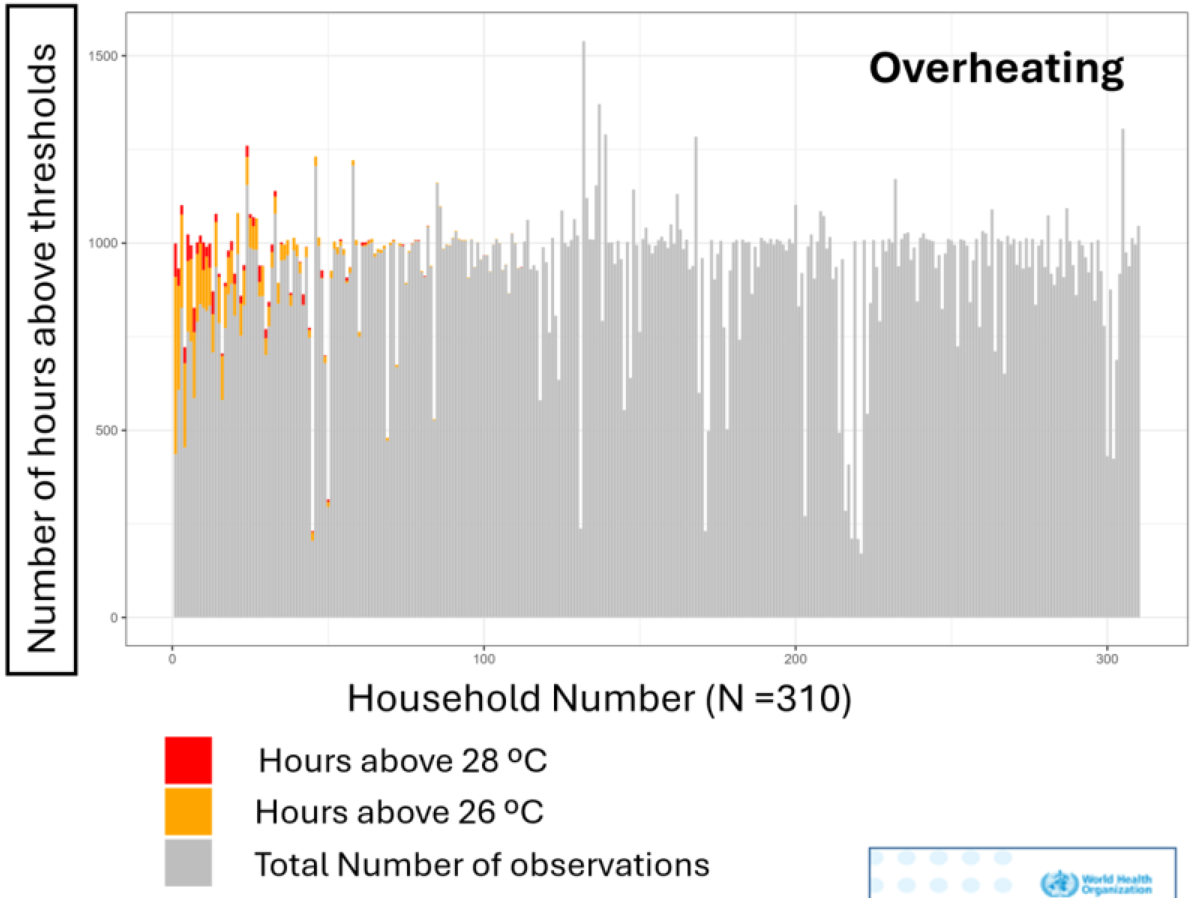
Cumulative number of households and observations collected during the deployment period March 2023- April 2024.



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

Thermal comfort – thresholds





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

And overheating .....

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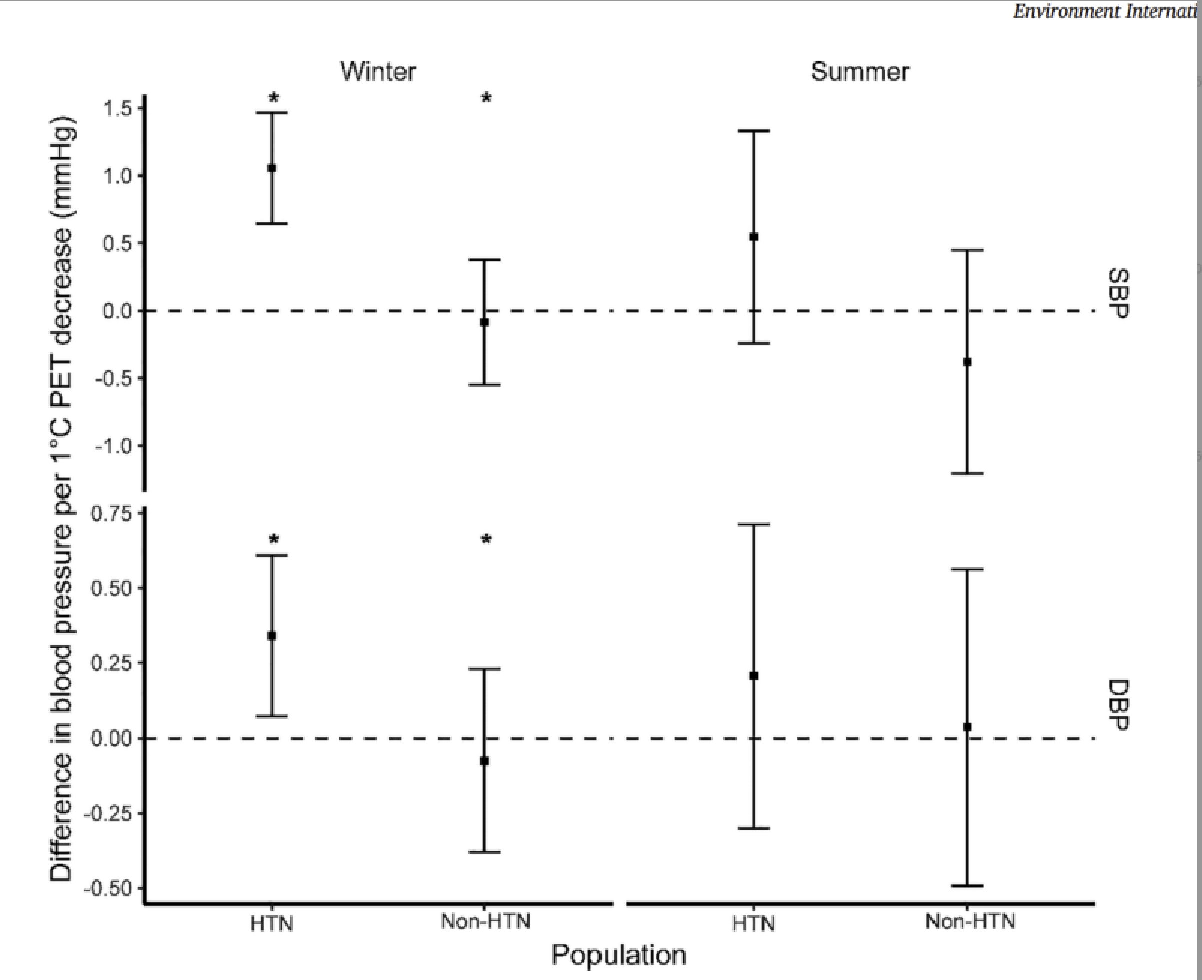
Thermal comfort – thresholds

Number of hours below thresholds



Estimated differences in Systolic (SBP) and diastolic blood pressure (DBP) of individuals with and without hypertension per 1 ^{0}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)

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

And overheating .....

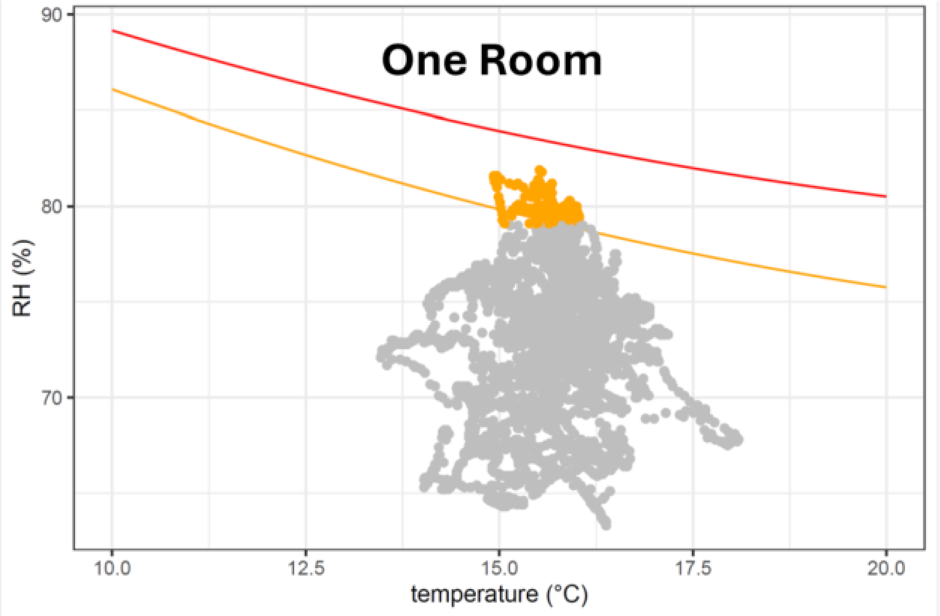
Hygrothermal conditions: Mould growth risk

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

A simple framework to assess health risks

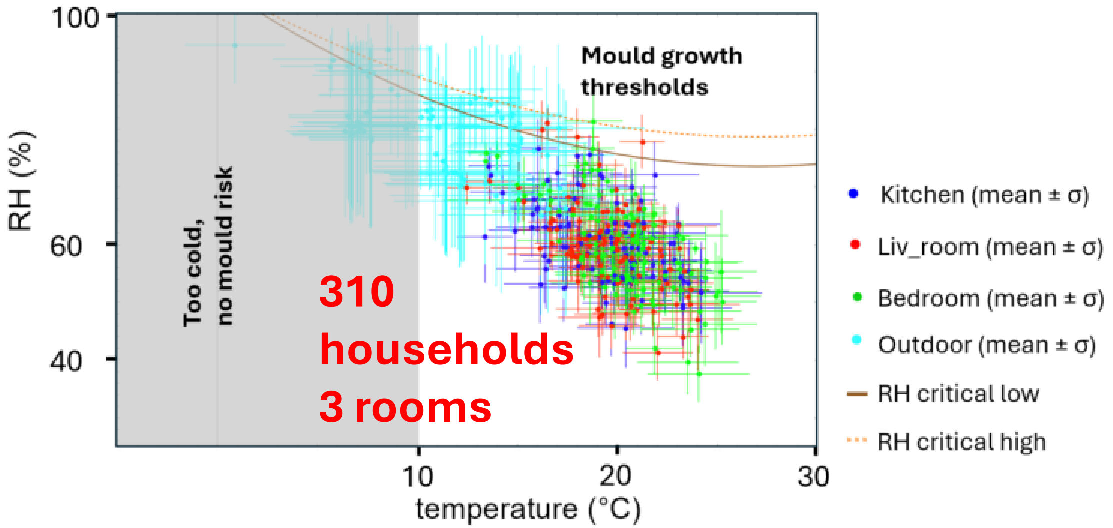
P-J model of Growth mould risk for CLASS-A materials

- Hygrothermal conditions where no mould growth is expected
- Hygrothermal conditions where mould growth is possible especially on vulnerable materials
- Hygrothermal conditions where mould growth is possible
- Growth curve line of lower critical RH
- Growth curve line of upper critical RH

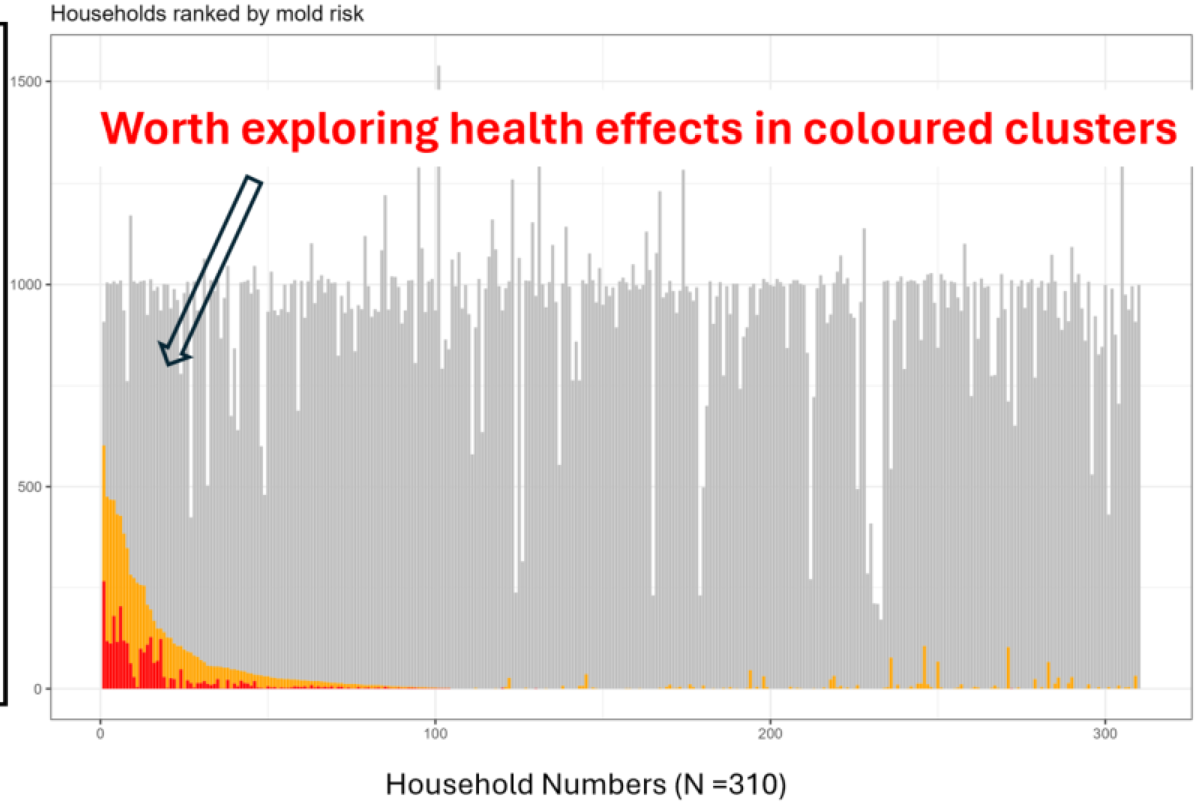


Example of one room where occupant complained of visible mould and severe respiratory symptoms

Indoor hygrothermal conditions (310 households)



Number of hours above thresholds (Hourly averages)



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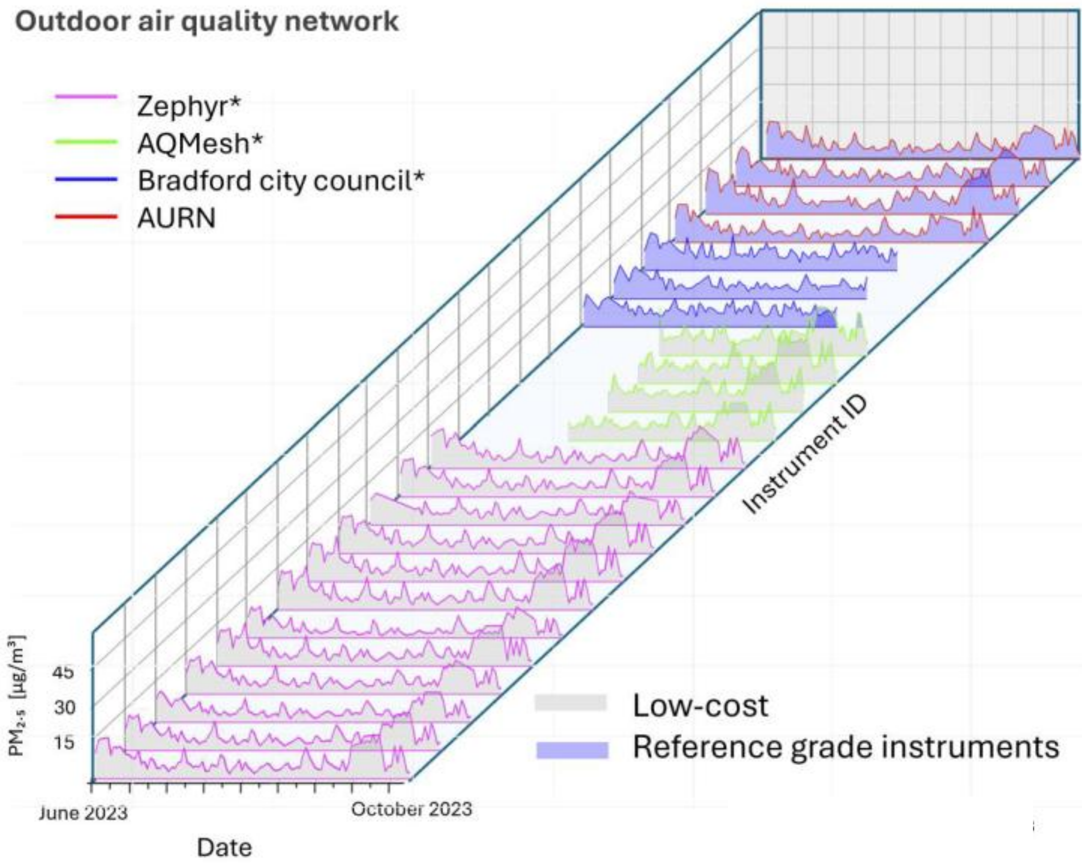
Outdoor air pollution levels (PM)



Outdoor PM levels are dominated by long-range transport

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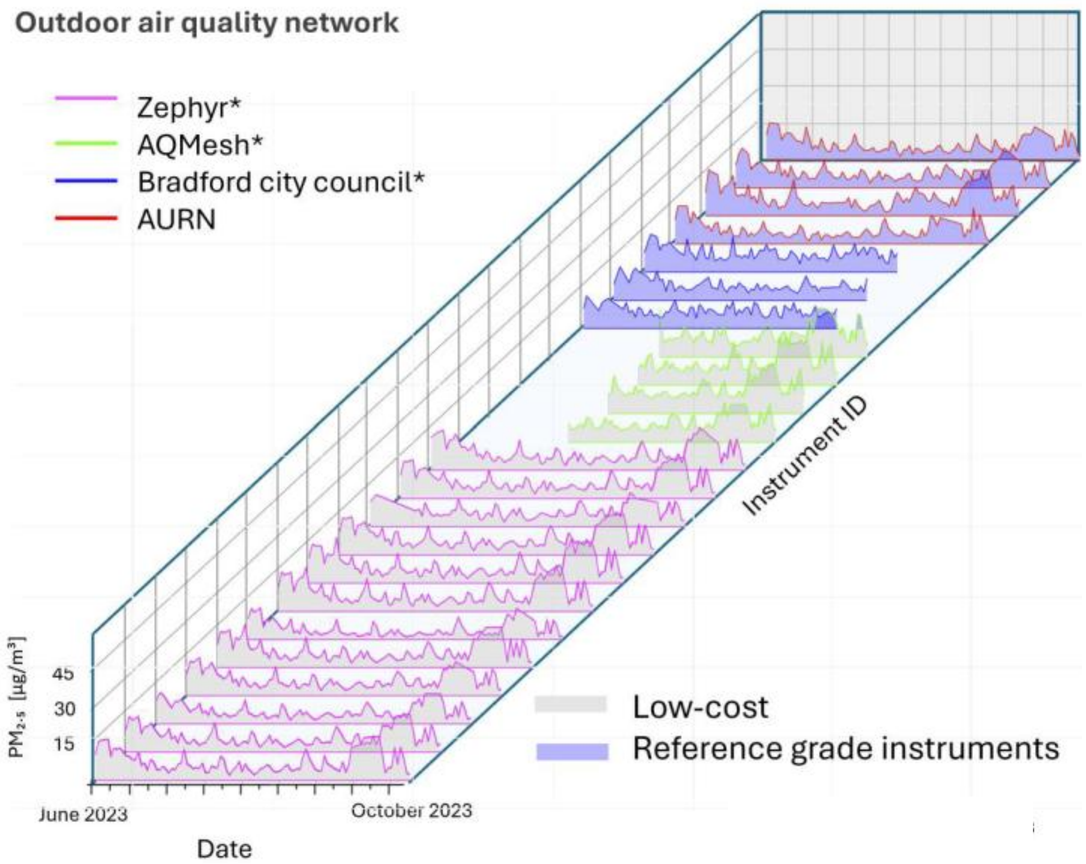
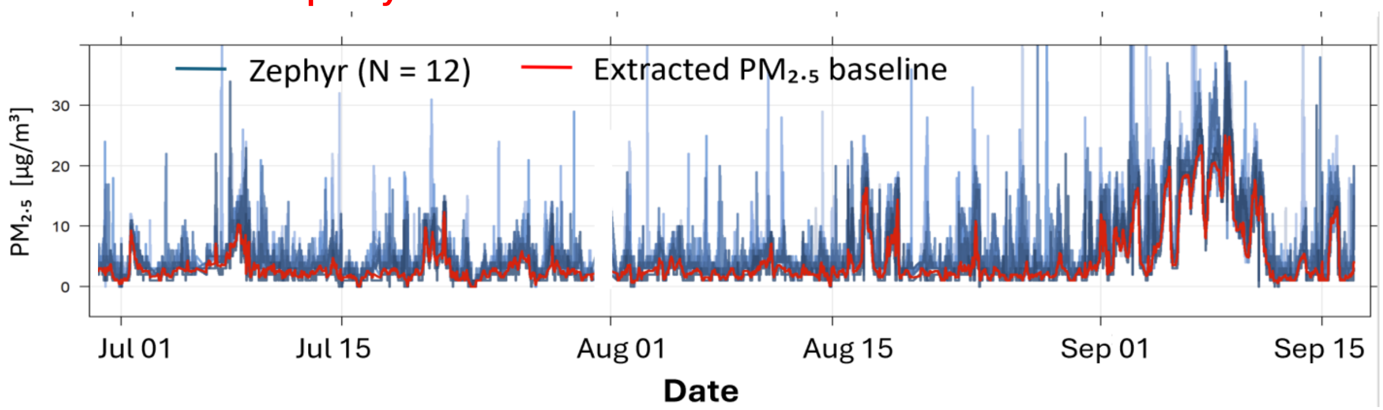
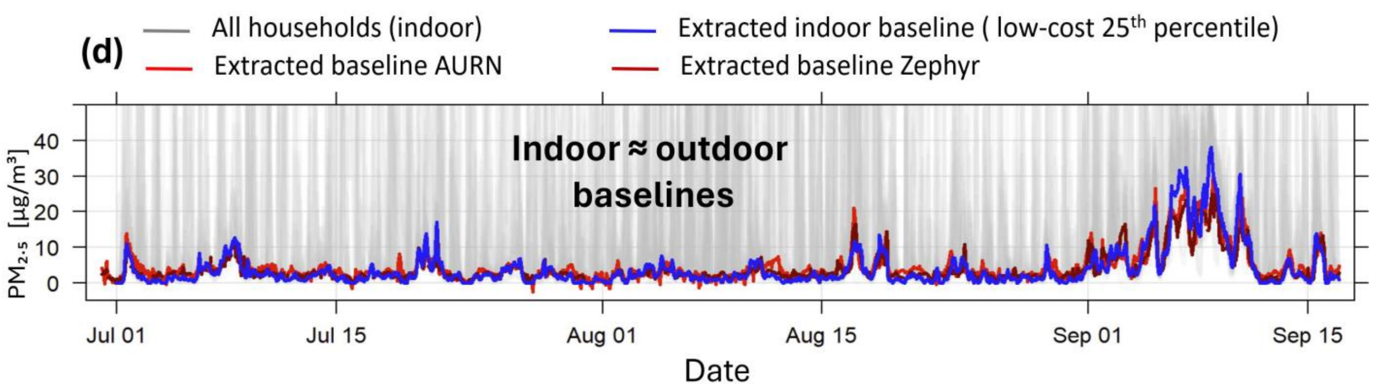
Outdoor air pollution levels (PM)







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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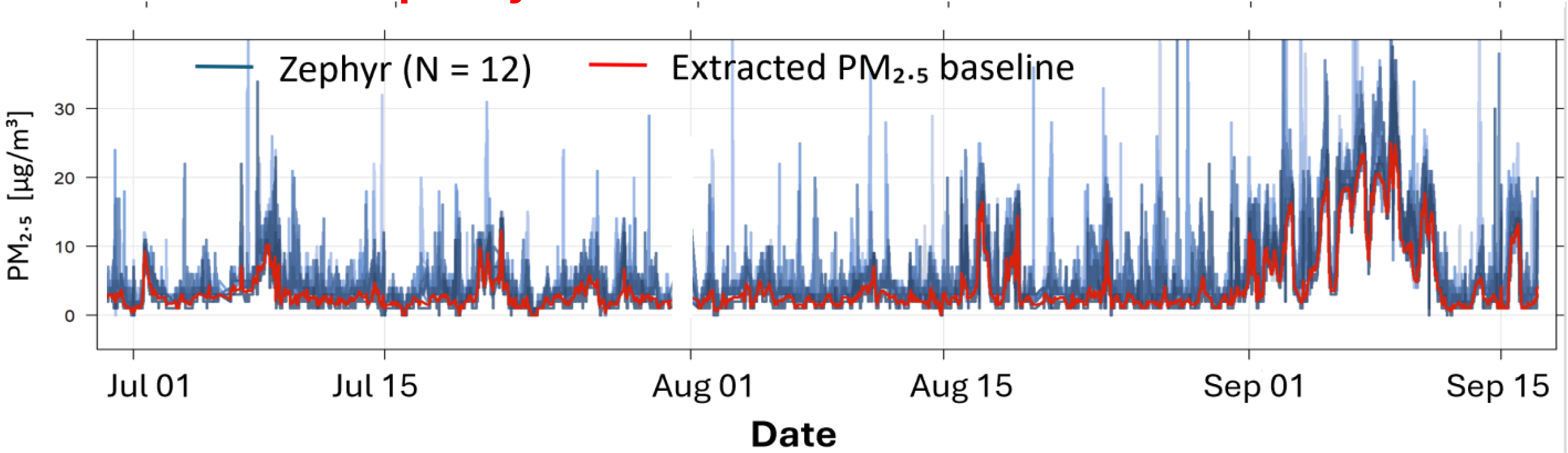
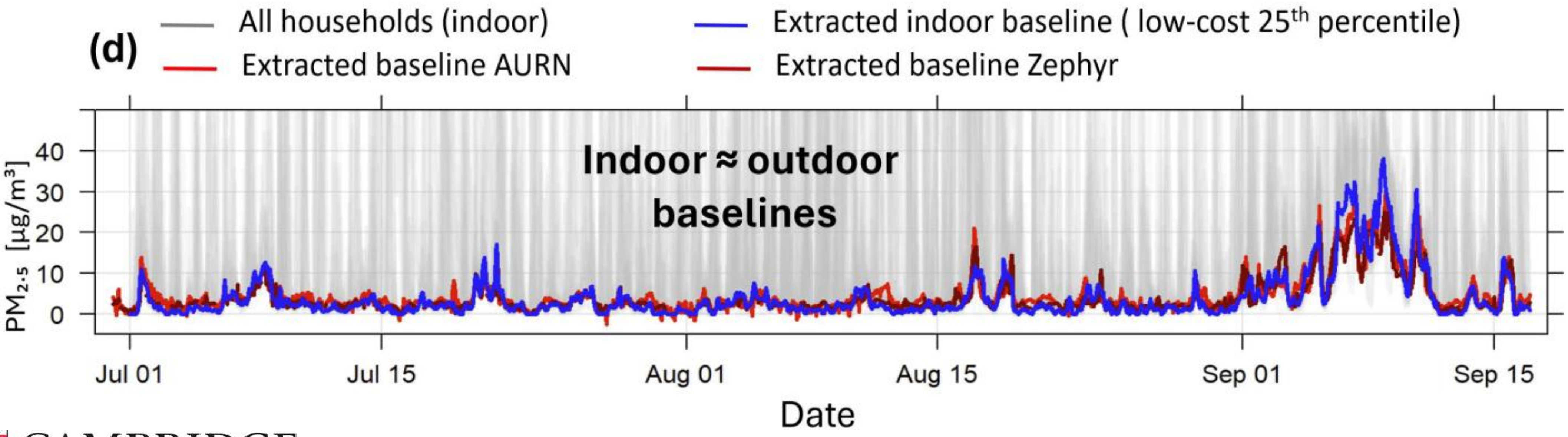
Outdoor air quality network



Indoor air quality network



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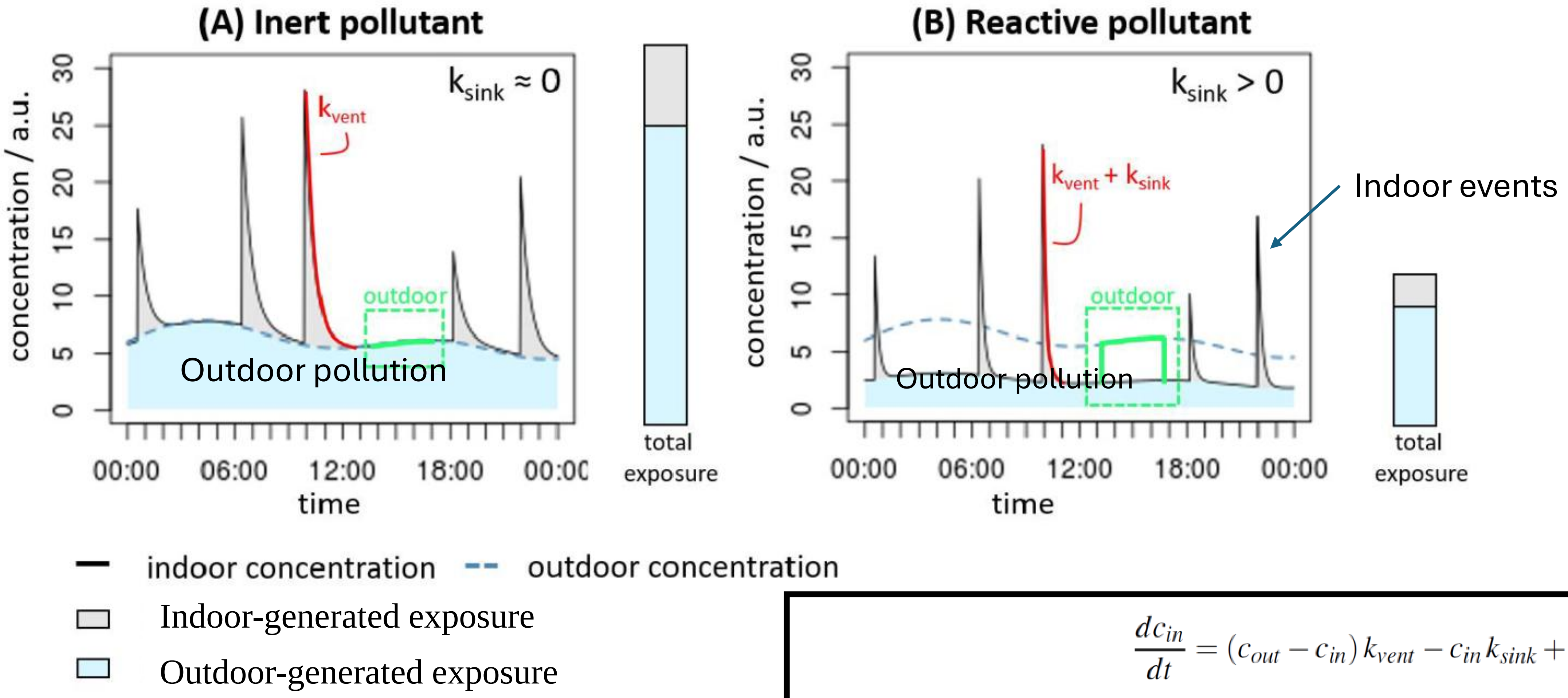
Conceptual model: Understanding air changes, sources and loss rate coefficients

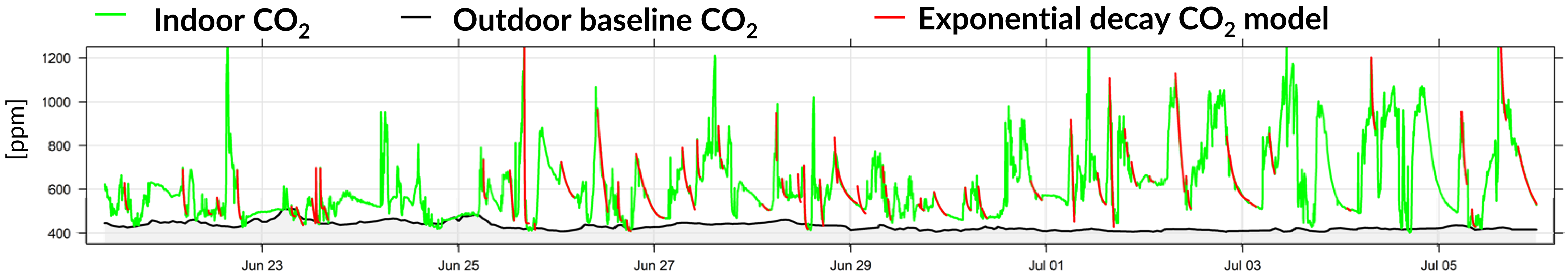


$$\frac{dc_{in}}{dt} = (c_{out} - c_{in})\,k_{vent} - c_{in}\,k_{sink} + S_{indoor}$$

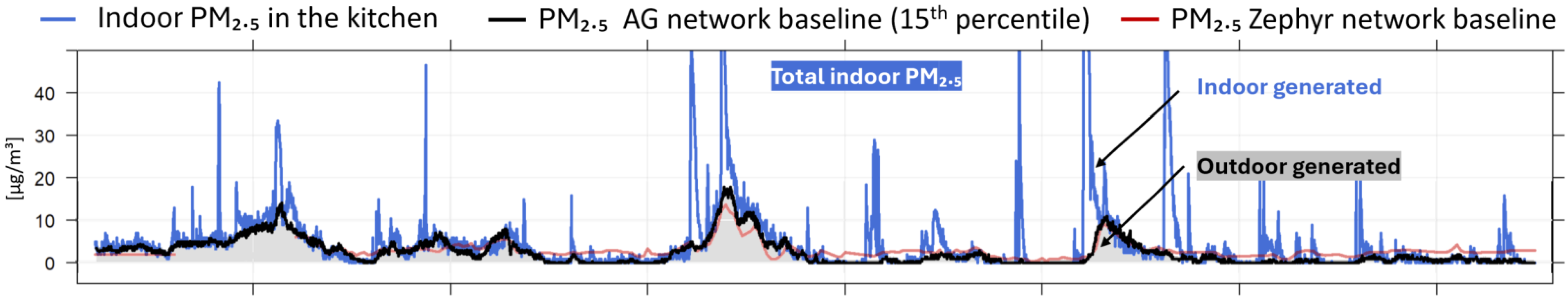
c_{out}, c_{in}	pollutant concentration outdoors and indoors (ppb)
k_{vent}	rate coefficient of building ventilation (hour^{-1})
k_{sink}	rate coefficient of indoor losses (pollution sinks) (hour^{-1})
S_{indoor}	emissions from indoor air pollution sources (ppb hour^{-1})

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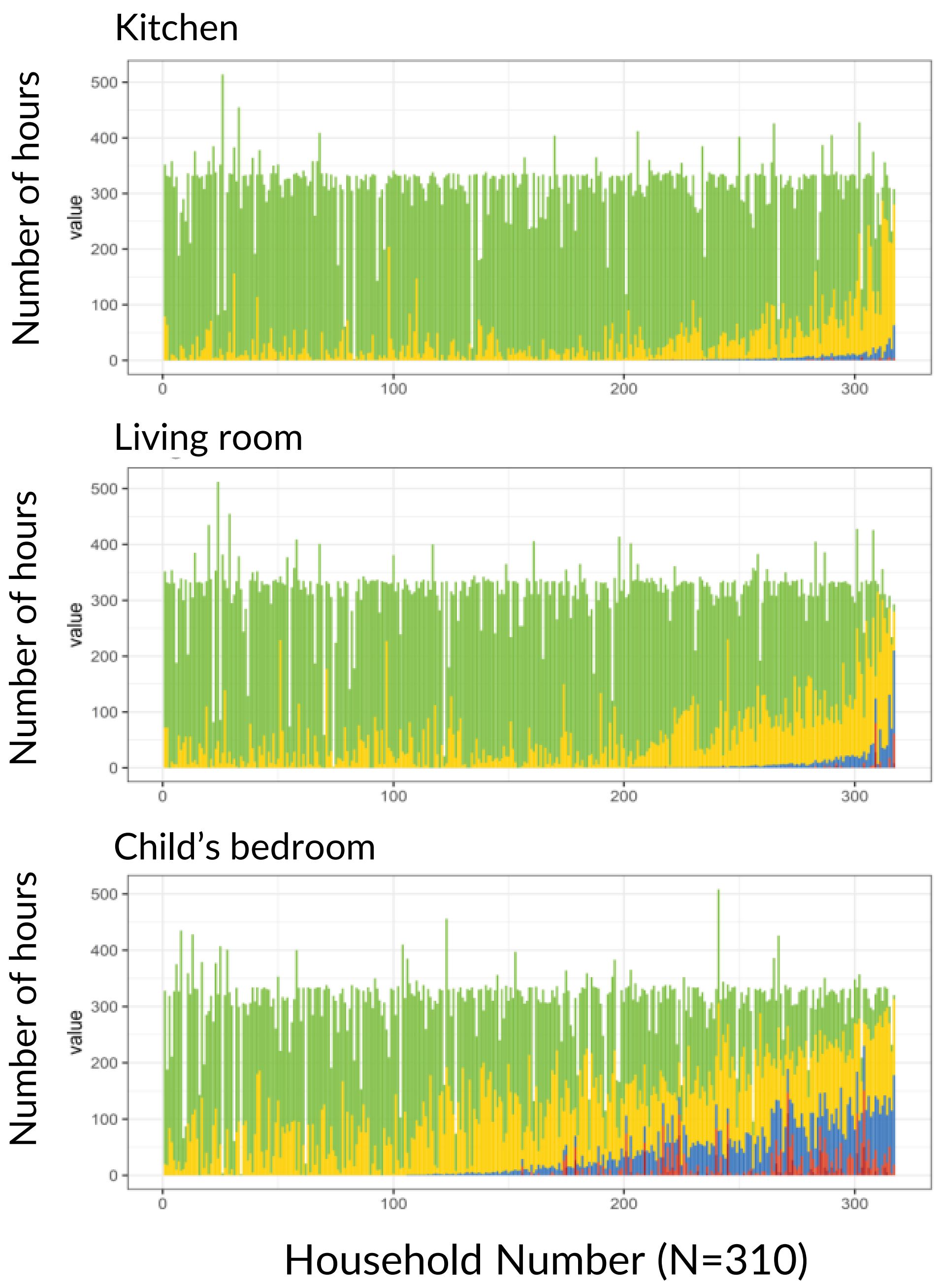
Carbon dioxide and air change rates per hour (ACH): All households

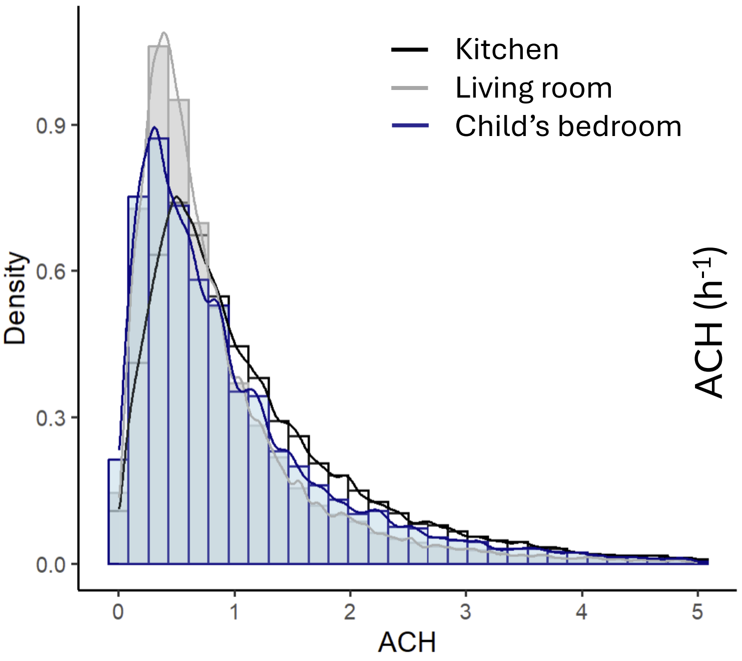
Category

- CO_2 levels < 1000 ppm
- 1000 ppm < CO_2 < 2000 ppm
- 2000 ppm < CO_2 < 3000 ppm
- 3000 ppm < CO_2 < 4000 ppm
- CO_2 levels > 4000 ppm

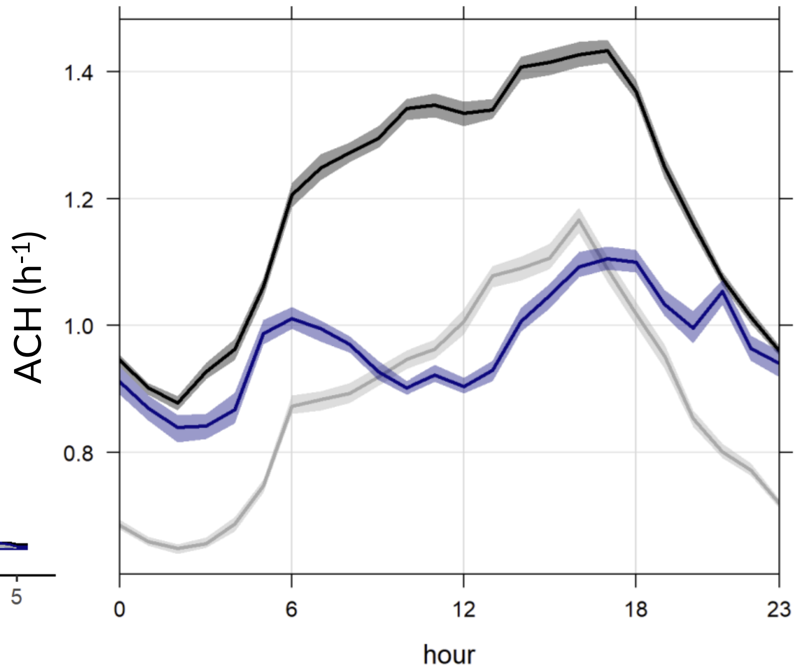


Highest ventilation rates in kitchens

ACH histogram plot



Diurnal pattern of ACH



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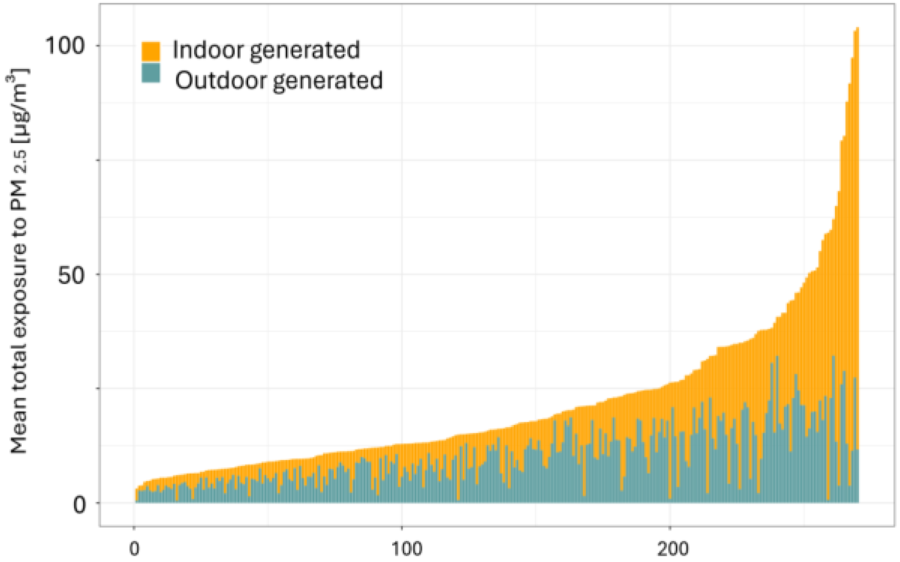
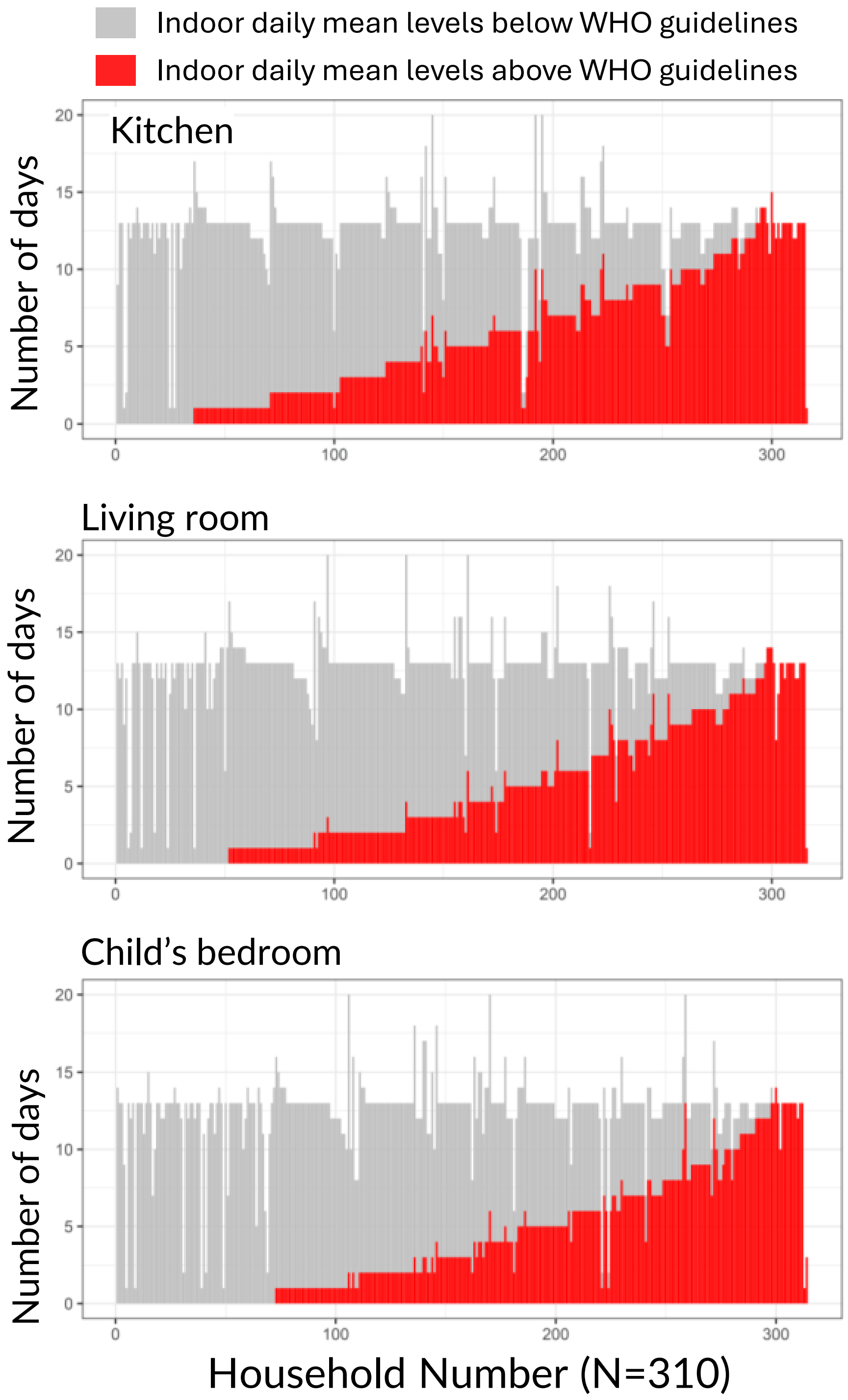
Highest CO_2 levels in children's bedrooms

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 $\mu g/m^3$



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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