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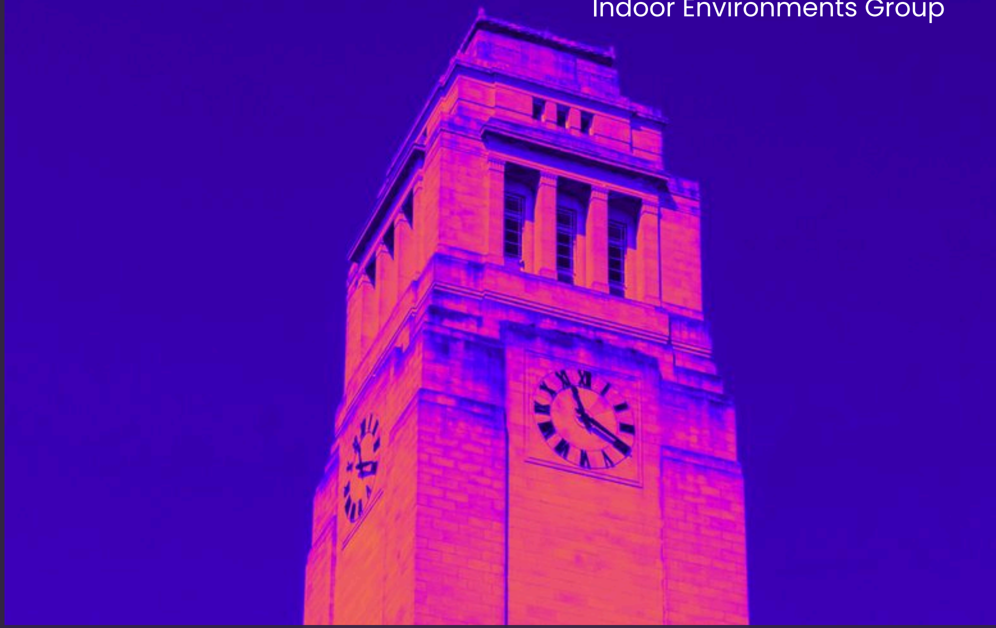

UKIEG 2025

THE IMPACT OF NET ZERO ON HEALTH AND INDOOR ENVIRONMENTS

Book of Abstracts

Edited by Marco-Felipe King
Martín López-García
Irene Mussio

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PROGRAMME

10:00 AM - Registration and Coffee

10:30 AM - Opening Remarks
Prof. Sani Dimitroulopoulou (UKHSA) &
Dr. Marco-Felipe King (University of Leeds)

10:40 AM - Keynote Address
"How to Save the City. A guide for emergency action"
Prof. Paul Chatterton (University of Leeds)
Chair: Prof. Sani Dimitroulopoulou (UKHSA)

11:15 AM - Session 1: Indoor Air & Ventilation
Chair: Dr. Marco-Felipe King (University of Leeds)

12:15 PM - Comfort Break

12:30 PM - Session 2: Networks and Research Funding
Chair: Dr. Issie Myers (Independent Consultant — Health, Policy & Environment)

1:10 PM - Lunch & UKIEG AGM - Poster Viewing

2:00 PM - Panel Discussion
Chair: Prof. Marcella Ucci (University College London)

2:30 PM - Session 3: Net-zero Transitions and Indoor Environment Quality
Chair: Dr. Sierra Clark (St George's, University of London)

3:30 PM - Coffee Break

3:50 PM - Session 4: Innovative Approaches to Healthy Indoor Environments
Chair: Dr. Alejandro Moreno-Rangel (University of Strathclyde)

4:50 PM - Closing Remarks
Prof. Sani Dimitroulopoulou (UKHSA)

5:00 PM - Drinks Reception & Networking

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WELCOME MESSAGE

Welcome to the historic city of Leeds for the UKIEG Annual Conference & AGM 2025, hosted by the Leeds Healthy Buildings Network. We gather at a truly pivotal moment, as the global journey towards net zero accelerates, transforming not only our energy systems but the very fabric of our daily lives. This year, we face a question of profound importance: *"The impact of net zero on health and indoor environments".* It is a theme that resonates deeply with the challenges and aspirations of our time.

The pursuit of a net-zero future is an ambitious and essential endeavour. Yet, as we strive to decarbonise our buildings, transport, and industries, we must navigate a complex landscape where choices made for the climate have direct consequences for human health and well-being. How do we ensure that our energy-efficient buildings also provide healthy indoor environments? How can we mitigate infection risks in environments designed for minimal energy use? And how do we guarantee that the transition to net zero is equitable, protecting the vulnerable and promoting healthier lives for all?

These are the critical questions that will animate our discussions here in Leeds. We are honoured to welcome leading voices to guide and inspire us. Professor Paul Chatterton, a distinguished expert from our host city's own University of Leeds, will deliver the keynote address of the conference on *"How to Save the City. A guide for emergency action"*. We also eagerly anticipate the insightful perspectives of Kate de Selincourt and Julie Godefroy, whose contributions promise to spark debate and illuminate the path forward.

This conference offers a rich programme, showcasing the breadth and depth of research in our field. From pioneering studies on indoor air quality and ventilation strategies to the vital work of research networks and hubs shaping the future of healthy environments, and from innovative solutions for sustainable buildings to critical analyses of net-zero transitions and their effects on the spaces we inhabit. The array of presentations and posters, covering everything from pathogen distribution in respiratory emissions to the challenges of overheating in modern homes, reflects the dynamism and collaborative spirit of the UKIEG community. We will also introduce six new research hubs and networks focusing on impact of climate change policies on indoor environmental quality and health: the CHILI Hub, the INHABIT Hub, the HEARTH Hub, the HESTIA Network, the Airhub and the BreatHE IN network.

Let this gathering in Leeds be a catalyst for new ideas, stronger collaborations, and renewed commitment. Our collective expertise, passion, and dedication are crucial as we work to ensure that the journey to Net Zero is a journey towards a healthier, more resilient, and more equitable future for all. Welcome, and let the conversations begin!

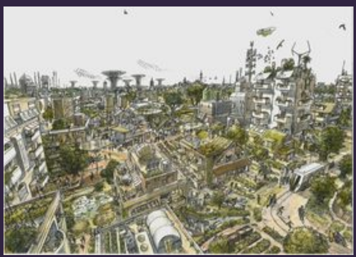
Professor Sani Dimitroulopoulou
UKIEG Chair, on behalf of the UKIEG Committee

Dr Marco-Felipe King
HBNLeeds co-lead, on behalf of the HBNLeeds

KEYNOTE
SPEAKER

Professor Paul Chatterton

Paul Chatterton is Professor of Urban Futures at the University of Leeds. He teaches, researches and takes action on the climate, ecological and social emergencies. Over the last 20 years he has teamed up with activists and campaigners to: stop fossil fuel use, transform derelict buildings, set up housing cooperatives, development trusts and community enterprises, support climate camps and social centres, take non violent direct action, campaign for migrant rights, and promote active travel. He has published over 50 peer reviewed articles and written 10 books including Low Impact Living, Unlocking Sustainable Cities and How to Save the City. Paul advises civic groups on climate emergency planning. He currently supports Climate Action Leeds in their 10 year vision to transform Leeds, and lives in the award winning cohousing community Lilac Grove.
Twitter: @paulchatterton9



By *James Mckay*

How to Save the City. A guide for emergency action

Paul Chatterton, Professor of Urban Futures, will explore *How to Save the City*, through as recent guide book he has written on the converging and accelerating emergencies of our age. While the climate emergency is the most urgent, we also face deep and long standing social inequalities in health, housing, work, gender and race, the breakdown of our natural world, and the deep ripples resulting from the Covid-19 pandemic. In this talk, Paul will explore the challenges ahead in our decade of transformation, and present cases from inspiring change makers who are getting in to emergency mode. He will also reflect on lessons from the award winning Lilac low impact co-operative cohousing project where he is resident and cofounder, and explore how to scale up and lock in benefits of community housing for creating net zero, affordable places.
www.howtosavethecity.org

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MEET THE
PANELISTS

Kate de Selincourt

Writer and Editor

Kate de Selincourt is a writer and editor with a focus on the intersection of health, environment, and policy. She has written extensively on the implications of building standards for public health and wellbeing, advocating for a more integrated approach to indoor environmental quality in the context of net-zero transitions.

Julie Godefroy

Head of Net Zero Policy, CIBSE

Julie Godefroy is a Chartered Engineer and the Head of Net Zero Plicity at CIBSE, leading key initiatives including the Net Zero Carbon Building Standard. Julie also works independently as a sustainability consultant specializing in building performance evaluation, climate resilience, and retrofit strategies.

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ORAL PRESENTATIONS

Session 1: Indoor Air & Ventilation
Chair: Dr. Marco-Felipe King (University of Leeds)

Session 2: Networks & Research Funding
Chair: Dr. Issie Myers (Independent Consultant - Health, Policy & Environment)

Session 3: Net-zero Transitions and Indoor Environment Quality
Chair: Dr. Sierra Clark (St George's, University of London)

Session 4: Innovative Approaches to Healthy Indoor Environments
Chair: Dr. Alejandro Moreno-Rangel (University of Strathclyde)

SESSION 1

INDOOR AIR & VENTILATION

The role of natural ventilation in long-range airborne transmission in a respiratory ward: a Monte Carlo approach.

Alexander Edwards[1,2], Martín López-García[2], Catherine J Noakes[2], Daniel Peckham[2,3], Marco-Felipe King[2]

[1]University of Bristol, Bristol, UK.
[2]University of Leeds, Leeds, UK.
[3]Leeds Teaching Hospitals NHS Trust, Leeds, UK.
Corresponding email: alexander.edwards@bristol.ac.uk

The 'Health Technical Memorandum 03-01' (HTM03-01) for UK hospitals suggests a preference for natural ventilation, with the aim of reducing energy consumption. However, due to openings to the ambient environment also being reduced or restricted for energy efficiency and increased building tightness, the efficacy of natural ventilation and attainment of recommended ward ventilation rates is unreliable. This creates uncertainty in the ability of natural ventilation to act as an effective mitigation strategy against airborne transmission. In this work, a deterministic model of a naturally ventilated UK hospital respiratory ward is extended using a Monte Carlo approach to incorporate stochastic effects and better understand the role of natural ventilation in long-range airborne transmission. The model utilises a coupling with a network-based ventilation model, CONTAM, to inform the airflow and natural ventilation of the indoor environment, incorporating the effects of transient weather conditions. The inclusion of stochasticity allows for the variation of outbreak parameters such as the infectiousness of the infector, accounting for population heterogeneity, and the day of the outbreak, influencing the airflow and natural ventilation. Results show that particular days (i.e., certain weather conditions) cause inherently high or low risk, regardless of the infectiousness of the infector. This is predominantly driven by the wind direction and thus, resulting inter-zonal indoor airflow. Additionally shown is the complexity of natural ventilation, with higher ventilation rates increasing the transport of infectious concentration, but not always leading to decreased infection risk, with the interplay between natural and mechanical ventilation also explored. This highlights the nuances present when assessing outbreaks and further shows the important role that ventilation plays in influencing the transmission of airborne pathogens.

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School-wide variation in indoor air quality: applying modal decomposition methods to large datasets.

Alice Handy[1], Sam Wood[1], Henry Burridge[1], The SAMHE Project Consortium

[1]Imperial College London, London, UK.
Corresponding email: a.handy23@imperial.ac.uk

The indoor air quality within schools can play a significant role in the health and well-being of children. Ensuring good air quality within schools is crucial in providing an environment that best supports learning and development. The Schools' Air quality Monitoring for Health and Education (SAMHE) Initiative brings together teachers, pupils and researchers through a citizen science approach to facilitate the large-scale monitoring of indoor air quality. Participating schools receive a free indoor air quality monitor which measures particulate matter (PM), carbon dioxide and temperature amongst other metrics. The SAMHE Initiative has enabled the collection of indoor air quality data at a higher temporal resolution across a greater number of schools in the UK than previously possible. We apply Robust Principal Component Analysis (RPCA) to this dense SAMHE timeseries dataset to identify temporal and school-wide variation of PM2.5 concentrations across 154 UK schools over the academic year 2023-2024. Complementary school-wide PCA analysis is also conducted across different air quality metrics and school factors to provide a deeper understanding of the sources of variation in air quality between SAMHE schools. We discuss the implications of the results for the management of school buildings and school ventilation in order to provide a good indoor environment with respect to different air quality metrics.

Computational fluid dynamics (CFD) modelling of toilet plume aerosol dispersion in a controlled chamber.

Ciara A. Higham[1], Martín López-García[1], Catherine J. Noakes[1], Louise Fletcher[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: C.A.Higham1@leeds.ac.uk

Shared toilet facilities can pose challenges for indoor air quality due to aerosol generation from flushing, known as the toilet plume. These aerosols can contain microorganisms as large as bacteria, which can lead to airborne or fomite exposure. Although expiratory aerosols have been widely studied, the behaviour and dispersion of toilet plume aerosols is less well understood.

This study uses Computational Fluid Dynamics (CFD), employing the Lagrange-Eulerian Discrete Phase Model (DPM) in ANSYS Fluent to model particle transport following a flush, investigating how ventilation rates and cubicle configurations influence particle dispersion and fate. Simulations were performed in a controlled mechanically ventilated chamber under three ventilation regimes (1.5, 3, and 6 ACH) and two layouts: i) an isolated toilet and ii) a toilet within a cubicle.

Results show that higher ventilation rates improve overall particle removal but can increase exposure by dispersing particles into the breathing zone. Cubicle partitions alter airflow patterns, leading to prolonged particle suspension and increased surface deposition, highlighting the role of room layout in exposure risk.

Alternative ventilation strategies using ceiling-mounted extract outlets positioned directly above the cubicle, were also tested. These adaptations enhanced aerosol removal, with 91.1% of particles extracted at the ventilation outlet compared to 47.7% with the baseline design at 6 ACH.

These findings have direct implications for the design of shared toilet facilities in workplaces, entertainment venues, and healthcare environments. Optimising airflow patterns and the positioning of ventilation outlets can significantly reduce exposure to toilet plume aerosols, supporting healthier indoor environments and contributing to infection control.

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Investigating ventilation strategies on public transport through the long-term environmental monitoring of operational London buses.

Oliver Wild[1], Filipa Adzic[1], Liora Malki-Epstein[1]

[1]University College London, London, UK.
Corresponding email: o.wild@ucl.ac.uk

London's public ground transport provides a basis for sustainable metropolitan mobility, widely depended on as an accessible and energetically efficient alternative to the mass usage of private vehicles. Many communities rely on public transport for essential mobility, but what this entails is the regular occupancy of contained and often crowded passenger cabins. Collective urban transport was quickly identified as an environment with one of the highest rates of COVID-19 propagation. Buses especially did not have the mechanical or power capacity to ventilate at rates advised for safer buildings in early COVID guidance. In May 2021, window blocks were deployed on buses across all fleets, aiming to maximise ventilation and mitigate the build-up of exhaled bioeffluents. This study investigates the efficacy of window blocks as a ventilation strategy by monitoring concentrations of metabolic CO2 inside the cabin to understand prolonged passenger exposure to exhaled breath. The dataset presents CO2 and temperature measurements from 15 fully operational buses over a span of 5 months (August to December 2022), providing high-resolution insight into the quality of ventilation provision in urban buses in reaction to seasonal climatic variation. The raw data was refined using actual routing times and delays to exclude idle periods. CO2 data was analysed to track peak concentrations and assess whether window blocks reduced the frequency of prolonged periods of poor air quality (e.g. during rush hours). The results show that partially open windows can pose challenges to the vehicle's heating/cooling units, creating difficulties in maintaining thermal comfort. This moreover increases energy consumption for air conditioning and heavily reduces vehicle range for electric buses due to excessive power demand. Striking a balance between well-ventilated, temperature-controlled cabins is essential for thermal comfort, air quality, and energy efficiency. This research informed the development of TfL's bus ventilation standards, ensuring passenger comfort and well-being.

SESSION 2

NETWORKS & RESEARCH FUNDING

HESTIA: Home Environment Solutions through Technology and Innovation for All.

Douglas Booker[1], Suzanne Bartington[2], Ruth Doherty[3], Helen Fisher[4], Rajat Gupta[5], Anna Mavrogianni[6], Alejandro Moreno-Rangel[7], Catherine J. Noakes[1], Amber Yeoman[8]

[1]University of Leeds, Leeds, UK.
[2]University of Birmingham, Birmingham, UK.
[3]University of Edinburgh, Edinburgh, UK.
[4]King's College London, London, UK.
[5]Oxford Brookes University, Oxford, UK.
[6]University College London, London, UK.
[7]University of Strathclyde, Glasgow, UK.
[8]University of York, York, UK.
Corresponding email: D.D.Booker@leeds.ac.uk

The UK housing stock is undergoing an unprecedented transformation to improve energy efficiency, reduce carbon emissions, and meet climate change mitigation targets. However, minimal attention is being paid to the impact of such a radical change on Indoor Environmental Quality (IEQ), physical and mental health and wellbeing, and equity.

Delivering low-carbon, healthy, and equitable homes through design and retrofit will need multiple different technologies; current efforts focus primarily on building fabric or system upgrades, yet there are significant opportunities through replacement technologies, smart devices, and consumer products. It is critical that we understand the combined impact of existing and emerging technologies, and their interactions with social and behavioural factors to deliver healthy and sustainable homes for the future.

In this presentation, I will introduce the Home Environment Solutions through Technology and Innovation for All (HESTIA) Network which will lay the foundation to address the challenge of how to most effectively implement technologies to design and retrofit housing to maximise human and environmental health co-benefits and reduce health inequalities. In HESTIA we have brought together researchers to establish a sustainable interdisciplinary network spanning engineering, the built and natural environmental sciences, health, and social sciences. HESTIA also includes multi-sector stakeholders -industry, local authorities, healthcare professionals, building engineers, architects, and end users- to co-design and deliver equitable housing research and innovative solutions, while also developing future research leaders equipped to work across disciplines and sectors.

HESTIA will create a new health-equity-centred engineering approach to home design and retrofit, integrating existing and emerging building technologies to maximise human and environmental health co-benefits, and minimise health inequalities. Our ultimate goal is to accelerate the creation of indoor home environments that meet Net Zero targets while promoting physical and mental health and wellbeing for all, considering the interface of technologies and social factors.

Introduction to the INHABIT net zero housing in real-world homes hub.

Ruth Doherty[1], Zongbo Shi[2], Anna Mavrogianni[3], James Milner[4], Bowen Liu[2], Suzanne Bartington[2], Sani Dimitroulopoulou[5], Helen Fisher[6], Rajat Gupta[7], Nigel Gilbert[8], Michael Davies[3], Rob Elliot[2], Sefi Roth[9], Zaheer Nasar[10], Chiara Giorio[11], Lia Chatzidiakou[11], Emma Marczylo[5], Mark Miller[1], Jamie Pearce[1], Christian Phrang[2], Ganga Shreedhar[9], William Bloss[2], Yuli Shan[2], Sue Jowett[2], Elisabeth Ralston[5], Duncan Grassie[5], Heather Price1[2]

[1]University of Edinburgh, Edinburgh, UK.
[2]University of Birmingham, Birmingham, UK.
[3]University College London, London, UK.
[4]London School of Hygiene & Tropical Medicine, London, UK.
[5]UK Health Security Agency, Salisbury, UK.
[6]Kings College London, London, UK.
[7]Oxford Brookes University, Oxford, UK.
[8]University of Surrey, Guildford, UK.
[9]London School of Economics, London, UK.
[10]Cranfield University, Bedford, UK.
[11]University of Cambridge, Cambridge, UK.
[12]University of Stirling, Stirling, UK.
Corresponding email: Ruth.Doherty@ed.ac.uk

The radical change needed to retrofit 29 million homes in the UK to meet Net Zero sector targets by 2050, offers an unprecedented opportunity to promote public health improvements and reduce inequalities. However, our insights into the complex interactions amongst the indoor environment, health, inequalities, behaviours, and regulatory and financial frameworks are limited. Comprehensive end-to-end assessment methods are needed.

INHABIT is a collaboration between 11 research organisations and 31 multi-sector partners that will establish and grow a transdisciplinary hub, which through co-design and co-production with stakeholders aims to deliver research that ensures health is at the centre of retrofit solutions happening in real-world net zero housing programmes. Our research is built around a systems approach that dynamically maps enablers and barriers for research translation to viable solutions across real-world housing types. Crucially, we will conduct a 2-year monitoring campaign in Central England using a non-randomised controlled trial in 400 homes to attribute observed exposure and health outcomes to retrofit interventions. Indoor air quality (CO2, PM2.5, PM10, TVOCs, temperature, and humidity) will be monitored utilising low-cost sensors, accompanied by detailed bioaerosol monitoring, lab molecular microbiology analyses and toxicological assessment of PM2.5. Health outcomes will be ascertained from household surveys such as the St George's Respiratory Questionnaire and the Short Warwick-Edinburgh Mental Well-being Scale. Our measurements will inform our development of an exposure health modelling framework that integrates street-scale and indoor air pollution modelling with archetype-based housing stock modelling incorporating exposure profiles with health modelling including 'synthetic population' methods, and health economic evaluation at multiple scales. Analysis of behavioural interventions will be a key focus to understand how healthy retrofit solutions can be achieved in practice. Findings will be broadened through wider stakeholder engagement including from Scotland's devolved administration facilitated by the Scottish researcH partnership for Air Pollution health Effects (SHAPE) network.

Addressing extreme heat and health inequalities in the net zero transition for vulnerable communities.

Rajat Gupta[1], Mike Davies[2], Anna Mavrogianni[2], Clare Heaviside[2], Shakoor Hajat[3], Ruth Doherty[4], Cathryn Birch[5], Candice Howarth[6]

[1]Oxford Brookes University, Oxford, UK.
[2]University College London, London, UK.
[3]London School of Hygiene & Tropical Medicine, London, UK.
[4]University of Edinburgh, Edinburgh, UK.
[5]University of Leeds, Leeds, UK.
[6]London School of Economics and Political Science, London, UK.
Corresponding email: rgupta@brookes.ac.uk

The UK's third National Adaptation Programme highlights the urgent need to build the evidence base to protect those most at risk. As the UK progresses toward a net zero building stock by 2050, it is essential that this transition delivers equitable health benefits, especially for vulnerable populations in multi-functional residential and healthcare settings. The 2022 heatwave, with temperatures above 40°C and over 3,200 excess deaths, exposed the growing health risks of extreme heat. By the mid-2030s, up to 90% of UK homes may be susceptible to overheating, yet current building regulations do not account for future climate conditions.

The newly established HEARTH Research Hub addresses this critical challenge by bringing together a transdisciplinary team to assess and realise the health co-benefits of net zero interventions, while reducing risks from extreme heat for vulnerable population groups in high-risk settings. We focus on those most at risk, such as older adults, people with chronic conditions, pregnant women, preschool children, and individuals in confined environments.

HEARTH adopts a stakeholder-led, whole systems-based, mixed-methods approach underpinned by co-production. This includes advanced climate modelling across regional, urban, neighbourhood, building, and indoor scales, and empirical data collection on heat exposure, occupant behaviour, and physical and mental health outcomes from over 200 homes, care settings, hospitals, and prisons. We will evaluate the health, equity, and economic outcomes of interventions such as retrofit, resilient new builds, and nature-based solutions. The five workstreams of HEARTH will produce high-resolution climate scenarios, quantify exposure inequalities, assess health impacts, evaluate current strategies, and co-design novel interventions. Cross-cutting themes will develop indicators, decision tools, and policy-relevant metrics.

In collaboration with 10 core organisations and 32 project partners across all UK nations, HEARTH will deliver actionable solutions to support a just, climate-resilient net zero transition - reducing health inequalities and easing pressure on health services.

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Child and adolescent health impacts of learning indoor environments under net zero: the CHILI hub.

Niloofar Shoari[1], Sani Dimitroulopoulou[1], Henry C Burridge[2], Rich Fry[3], James Milner[4], Michael Davies[1], Douglas Booker[5], Anna Mavrogianni[1], Michaela James[3], Sarah West[6], Lynda Dunlop[6], Catherine J. Noakes[5], Matthew Lilliman[1], Dejan Mumovic[1], Pia Hardelid[1]

[1]University College London, London, UK.
[2]Imperial College London, London, UK.
[3]Swansea University, Swansea, UK.
[4]London School of Hygiene & Tropical Medicine, London, UK.
[5]University of Leeds, Leeds, UK.
[6]University of York, York, UK.
Corresponding email: n.shoari@ucl.ac.uk

Schools and nurseries are crucial environments where children develop, learn, and eventually take exams which impact their education, health and future incomes. Schools also account for 15% of public sector carbon emissions. To meet our 2050 net zero target, schools need to be retrofitted or redesigned to become more energy-efficient. While these measures reduce heating demands, they may compromise indoor air quality (IAQ) and increase overheating. For children and young people (CYP) who spend much of their time indoors at school, these environmental changes could have significant consequences for both physical and mental health. The Child and Adolescent Health Impacts of Learning Indoor Environments under Net Zero (CHILI) Hub is a UKRI/NIHR funded, pioneering, research hub to investigate these effects and develop health-focused solutions. CHILI brings together a transdisciplinary team of experts in engineering, epidemiology, clinical medicine, mental health, and education to conduct the most extensive study of IAQ and overheating in primary and secondary schools across England and Wales, and combine this with building physics models, and analyses of linked, national and regional education and health data. Our work integrates six main objectives: (1) Mapping how IAQ and heat vary across school environments; (2) Understanding their impacts on CYP's health and school attendance; (3) Modelling long-term effects of net zero building strategies; (4) Evaluating interventions such as air filtration, overheating prevention, and behavioural adaptations; (5) involving CYP and school communities as citizen scientists to develop practical solutions, and (6) engaging closely with government, charities and teaching unions . CHILI will provide evidence to ensure net zero school transitions support both sustainability and CYP's health and well-being. This presentation will highlight our approach, key milestones, and the broader implications for creating healthier learning environments.

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BreatHE IN: Building healthier environments indoors network.

Bruño Fraga[1], Suzanne Bartington[1], Christian Pfrang[1], Sonia Contera[2], Zhiwen Luo[3]

[1]University of Birmingham, Birmingham, UK.
[2]University of Oxford, Oxford, UK.
[3]Cardiff University, Cardiff, UK.
Corresponding email: b.fraga@bham.ac.uk

BreatHE IN will generate 1) a network to champion Healthier Environments and increase public awareness about the benefits of strengthening this research area; 2) a holistic, cross-disciplinary framework to transfer knowledge across academia, industry and the public sector; 3) a hub to fund and promote innovative ideas in this new area of research.

More than 1.5 M new homes are to be built in the next five years in the UK, where 80% of the UK housing stock is more than 40 years old. The COVID-19 pandemic brought awareness on the presence of airborne pollutants and pathogens - particularly in indoor environments. The popularisation of sensors and filters highlighted the importance of air quality within built environments and the need for appropriate ventilation. However, four years later, and despite relevant technological advances, there is still a need for comprehensive methodologies and tools to implement the lessons learned in construction practice. It is crucial to incorporate health considerations in the new wave of building and retrofitting.

BI will promote high-risk/high-reward interdisciplinary research. The network will develop roundtables and sandpits and offer participants the possibility to apply for pump-priming funding to develop pilot or proof of concept studies. The Network will make particular emphasis in building a legacy. We will set up a mentorship scheme and allocate funds for bursaries for early career researchers and those in underrepresented groups to train the new generation of researchers in the field. We will facilitate and foster the co-creation of long-term collaborations and research proposals.

BI's approach puts the building environment in the centre to cut through disciplinary barriers. We will promote and fund research directed to further our understanding and improve the air quality and thermal comfort of indoor environments and to reduce or suppress the spread of pollutants and airborne pathogens. BI is also interested in strategies to co-deliver high air quality standards and energy efficiency. Finally, we also want to understand how these aspects can affect (and improve) the life and mental health of the building's occupants and users.

Airhub: Engineering healthy indoor environments.

Abigail Hathway[1], Sierra Clark[2], Chantelle Wood[1], Simon Johnston[1], Gergo Baranyi[3], Heather Elphick[4], Jonathan Higham[5], Sarah West[6]

[1]University of Sheffield, Sheffield, UK.
[2]City St George's, University of London, UK.
[3]University College London, London, UK.
[4]Sheffield Children´s NHS Foundation Trust, Sheffield, UK.
[5]University of Liverpool, Liverpool, UK.
[6]University of York, York, UK.
Corresponding email: a.hathway@sheffield.ac.uk

Airhub is a new EPSRC Micro-network plus launching in Autumn. Our aim is to create a comprehensive roadmap to deliver the research required to design and investigate the engineering interventions required to improve the health of our indoor environments. The network will focus on particulates inside, explicitly exploring: How much and what is in PM2.5 indoors, what are its health impacts, and what are the most effective and equitable ways to reduce those impacts?

As a network we are seeking to engage with a variety of stakeholders from academia, local authorities, public health, and industry through a number of workshops and research sandpits. We will be holding an open competition for funding to deliver pilot studies in order to develop the road map and associated future collaborative grant proposals.

Some of our specific events include: a collaborative event with the UKs birth to death cohorts and large administrative health datasets, co-designing feasibility studies with members of the public who suffer from symptoms related to poor indoor air quality, and trialing sampling methods. We will also be exploring the ethical implications related to personal sampling with a view to generating best practice guidelines. We welcome involvement from early career researchers and will host monthly online "coffee breaks" to share research ideas. In mid-2026 we will be hosting a sandpit event to define feasibility studies to be funded under our flexible fund. We hope to welcome a wide range of stakeholders to this event and attendance will be via open application.

Partners: Doncaster City Council, UK Indoor Environments Group (UKIEG), London Borough of Newham, Barnsley Metropolitan Borough Council, Sheffield Teaching Hospitals NHS Foundation Trust, Swansea University, University of Leeds, Sheffield City Council

SESSION 3

NET-ZERO TRANSITIONS AND INDOOR ENVIRONMENT QUALITY

What impact do energy efficiency measures and modern construction techniques have on indoor radon levels in the UK?

Zornitza Daraktchieva[1]

[1]UK Health Security Agency, Chilton, UK.
Corresponding email: zori.daraktchieva@ukhsa.gov.uk

Radon, 222Rn, a radioactive, colourless and odourless gas, is the largest source of radiation exposure for most of the population and a proven carcinogen (WHO 2008). Measurements in homes showed that half of the annual radiation dose in the UK comes from exposure to indoor radon (Oatway et al 2016). Moreover, some authors have estimated that 8% of lung cancer deaths in the UK are attributed to radon (Gaskin et al 2016).

The influence of energy saving measures on indoor radon levels was examined using the results of several UK studies (Milner et al 2014, Symonds et al 2019, Daraktchieva 2021).

Energy efficiency measures and modern construction techniques increase the airtightness of buildings. Radon tends to accumulate inside dwellings because the building envelope becomes more airtight than the foundations. Retrofitted homes with energy saving measures are likely to have higher radon concentrations than homes without such measures. The homes with installed double glazing, wall or loft insulation, and draught-proofing were compared with a controlled sample of homes without any recorded energy saving measures.

Measurements in two occupied rooms of studies including dwellings indicated that the building practices and energy efficiency measures can adversely affect the indoor radon concentrations.

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HEALTHY BUILDINGS NETWORK LEEDS

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Exploring the consequences of climate change mitigation policies for indoor air quality.

Duncan Grassie[1], Sani Dimitroulopoulou[1], Rohit Chakraborty[1], Michael Davies[2], Tracy Gooding[1], Kaja Milczewska[1], Marcella Ucci[2], Tim Sharpe[3]

[1]UK Healthy Security Agency, Salisbury, UK.
[2]University College London, London, UK.
[3]University of Strathclyde, Glasgow, UK.
Corresponding email: duncan.grassie@ukhsa.gov.uk

Climate change mitigation policies include improving energy efficiency in buildings. For heating-dominated countries, heating demand in domestic and non-domestic buildings can account for as much as 15% and 20% of national carbon emissions, respectively, with additional cooling demand required in warmer countries. While energy efficiency design and retrofitting buildings can help achieve net zero, by reducing energy demands, improvements in ventilation also need to be considered concurrently. This will prevent unintended health impacts from poor indoor air quality (IAQ) caused by increased air tightness and internal temperatures.

Through a literature review, the impact of energy efficiency policies on ventilation and IAQ, including particulates, volatile organic compounds (VOCs), radon, mould and other biological contaminants, have been collated for heating-dominated countries. Policies enacted vary by country and include: (a) statutory guidance on building thermal properties and ventilation provision, (b) certification schemes to promote energy efficiency and health best practice standards and (c) suites of methods used to achieve retrofit in practice.

Provision of adequate ventilation is important in airtight buildings, particularly where the geology means that radon levels are more likely to be high, or indoor pollutant sources are present, from building materials and furnishing, consumer products and occupant activities (e.g., solid fuel burning and drying clothes indoors). Effective ventilation can achieve a balance between removal of indoor-generated pollutants and ingress of outdoor pollutants, such as traffic generated particulates, and can also control the hygrothermal conditions, which promote the growth of mould and other biological contaminants. Correct maintenance and operation of natural and mechanical ventilation systems can be as important as provision itself, and other aspects of indoor environment quality such as thermal comfort and noise should also be considered alongside IAQ concerns. This work has been provided as a chapter to a forthcoming book explaining future perspectives relating to air quality.

Overheating challenges in dwelling conversion: a case study of London terraced houses.

Yiqing Liu[1], Sue Grimmond[1], Zhiwen Luo[2]

[1]University of Reading, Reading, UK.
[2]Cardiff University, Cardiff, UK.
Corresponding email: dg829684@student.reading.ac.uk

The average household size (HHS) in UK is shrinking around 1.2% per year, with increasing number of people living alone. To meet this smaller household need, building retrofitting also now includes dwelling conversion (DC) that split existing dwellings into multiple smaller units. However, a reduction in HHS, coupled with an increased number of households, may result in less efficient energy sharing within the unchanged building volume. Activities such as cooking may occur more frequently, leading to higher appliance energy use and increased internal heat gains. The latter is becoming more important to evaluate given overheating risks, especially in well-insulated buildings. In this study, the UK time use survey (TUS) provides activity information for use with building energy modelling, allowing us to assess how dwelling conversion impacts the indoor overheating risk across different building age bands in London's summer. Our results show DC accompanied by increased occupancy density, significantly exacerbate both the duration and severity of overheating in both older and newer buildings, whereas the retrofitting effects are limited under decreased occupancy density. Our findings highlight the importance of internal heat gains driven by changed household size when evaluating the indoor overheating. The insights derived from this analysis will provide guidance for building refurbishment practitioners and other stakeholders to consider these factors when undertaking the dwelling conversion.

How warm is warm enough? Measuring comfort with radiant heating in a Scottish passive house.

Alejandro Moreno Rangel[1], Kirsty Maguire[2]

[1]University of Strathclyde, Glasgow, UK.
[2]Kirsty Maguire Architects LTD, Newport on Tay, UK
Corresponding email: alejandro.moreno-rangel@strath.ac.uk

This study explores the thermal performance and comfort implications of integrating infrared radiant heating in a certified Passivhaus dwelling in Scotland. As the nation prepares to adopt a Passivhaus-equivalent energy standard by 2025, practical evaluations of low-energy heating strategies become increasingly critical, particularly those that challenge conventional definitions of comfort.

The research involved a full-year Building Performance Evaluation of a 137.8m^2 detached home equipped with an MVHR system and infrared heating panels. Indoor environmental parameters -temperature, relative humidity (RH), and CO2 levels- were continuously monitored at 15-minute intervals throughout 2024. Energy consumption was submetered to assess heating demand and total usage.

Findings indicate that indoor air temperatures frequently fell below typical comfort thresholds (20–25ºC), particularly in bedrooms, yet no overheating risk was identified using both adaptive and static criteria. Occupants reported thermal satisfaction, suggesting that infrared heating -by directly warming surfaces and occupants rather than air- can influence comfort perception in ways not captured by standard air temperature metrics. RH levels remained within recommended ranges in most spaces, and CO2 concentrations consistently stayed below 1,000 ppm, affirming effective ventilation through MVHR. Estimated heating energy use was 12.98 kWh/m^2 annually, well below the Passivhaus threshold of 15 kWh/m^2. These results highlight the viability of radiant electric heating as a low-energy alternative to more complex systems, particularly when combined with renewable energy sources.

This case study demonstrates the importance of revisiting how thermal comfort is defined and measured in ultra-low-energy homes. As Scotland -and other regions- move toward net-zero housing standards, greater consideration must be given to occupant behaviour, heating modes, and perceived comfort in shaping performance benchmarks and policy frameworks.

HEALTHY BUILDINGS NETWORK LEEDS

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SESSION 4

INNOVATIVE APPROACHES TO HEALTHY INDOOR ENVIRONMENTS

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Cooking, culture, and clean air: a participatory approach to improving indoor air quality in energy-efficient homes.

Satish BK[1], Kamal Haddad[1], Rawan Jafar[1], Simon Lannon[1]

[1]Cardiff University, Cardiff, UK.
Corresponding email: Satish.BK@cardiff.ac.uk

Indoor air quality (IAQ) is a critical yet often overlooked determinant of health and wellbeing, particularly in energy-efficient homes where airtight construction can exacerbate the accumulation of pollutants. Previous research identified disproportionately high CO2 and particulate matter levels in homes of British-Asian residents due to extended cooking durations and limited ventilation strategies. Recognising that standardised air quality solutions may not align with cultural lifestyles. This project adopts a participatory approach to engage residents, policymakers, and housing associations in developing tailored, community-driven interventions. A mixed methods approach was used to explore the intersection of cultural cooking practices, user behaviour, and IAQ within ethnic minority households in Cardiff, UK.

Residents were provided with air quality monitoring devices that enabled them to observe pollutant levels during everyday cooking activities, fostering self-reflection and data-driven behavioural change. Diary logs and qualitative interviews captured their lived experiences, while co-design sessions ensured that practical recommendations were embedded within residents' cultural contexts.

A key outcome of this project is the Good Practice Guide, which was developed using insights from the co-design process. Through an iterative, participatory approach, residents and stakeholders co-created a resource that translates scientific research into practical, culturally sensitive IAQ interventions. The guide promotes adaptive ventilation strategies that are responsive to both energy-efficient housing constraints and traditional cooking practices, offering pragmatic solutions for reducing indoor pollutant exposure without disrupting cultural norms. By integrating real-life experiences and monitoring data, the guide also outlines behaviour-driven modifications that empower residents to make informed decisions about their indoor environments. Furthermore, it provides housing associations with clear strategies to support IAQ improvements in social housing, while offering policy recommendations for embedding IAQ considerations into Welsh Housing Quality Standard (WHQS) across housing associations, ensuring that indoor air quality becomes a fundamental component of housing policy as we race towards net-zero built environment.

Rethinking indoor air quality: green wall biofilters, and net zero building design.

Dominic Clyde-Smith[1], Pete Carvell[1]

[1]We Design For. . ., UK.
Corresponding email: dominic@d-for.com

Net Zero buildings face a critical issue: balancing energy efficiency and indoor air quality (IAQ). Efforts to reduce energy consumption often lower ventilation rates, leading to pollutant buildup, occupant discomfort, and health risks. This presentation explores how improper or insufficient ventilation contributes to stagnant, contaminated air in tightly sealed Net Zero environments. To counteract these issues, this study evaluates a sustainable alternative: the integration of hydroponic phytoremediation systems via biofilter green walls. These systems were assessed through a laboratory study of Biotecture' s Active Air Unit (AAU), designed to actively draw air across plant root zones to enhance the uptake of nitrogen dioxide (NO2), particulate matter (PM2.5, PM10), and volatile organic compounds (VOCs). Results from controlled environmental chamber testing revealed that the AAU achieved a Clean Air Delivery Rate (CADR) of 33.49 L/S for NO2 at 62% efficiency, significantly reducing NO2 concentrations to ambient levels within two hours, over one hour faster with the inclusion of plants. For PM10 and PM2.5, the AAU demonstrated a CADR of 3.7 L/S (17% efficiency) and 11.38 L/S (28% efficiency). AAU consistently outperforms controls and non-planted setups. Though no significant CO2 reduction was observed (due to lighting limitations), the biofiltration unit showed promising humidity control and pollutant breakdown potential. This research underscores the viability of green wall biofilters as a complementary strategy to mechanical ventilation especially in buildings striving for Net Zero targets, by enhancing IAQ, occupant wellbeing, and biodiversity. A systems-thinking approach that rebalances energy, air quality, and human health is essential for the future of sustainable design.

Behaviour nudging for user engagement in smart blinds control: a pilot study on behaviour change and indoor environmental enhancement.

Wen-Ting Li[1], Alessandra Luna-Navarro[2], Pedro de la Barra Luegmayer[2], Michele W.T. Mak[1], Han Fang[1]

[1]University of Leeds, Leeds, UK.
[2]Delft University of Technology, Delft, Netherlands.
Corresponding email: cnwli@leeds.ac.uk

Automated adaptive blinds have the potential to improve energy performance and occupant comfort in buildings. However, user disengagement and frequent manual overrides challenge their effectiveness, often stemming from a lack of perceived control and insufficient awareness of environmental benefits. Behavioural nudging, particularly through gamification, offers a promising approach to encourage user interaction with automated systems without compromising autonomy. Despite its success in fields such as health and education, limited research has explored its application in environmental control systems. This study investigates how gamification-based nudges influence user engagement, awareness, and decision-making in the context of smart blinds. A structured questionnaire was proposed to explore the impact of gamification elements -such as feedback, incentives, and social comparison- while accounting for user-specific factors like personality and familiarity with smart technologies. Preliminary results indicate that personalised feedback and rewards enhance engagement and system acceptability. These findings offer early guidance for designing human-centric adaptive systems that balance automation with user participation, supporting energy efficiency and well-being in indoor environments.

HEALTHY BUILDINGS NETWORK LEEDS

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Optimization of indoor space planning in a repurposed office to residential building using multi-objective genetic algorithm.

Amany Khalil[1], Bhargav Macha[1], Noorfazlenawati Mohamad Nor Azli[1], Michael Davies[1], Eleni Oikonomou[1], Ben Clifford[1], Anna Mavrogianni[1], Rokia Raslan[1]

[1]University College London, London, UK.
Corresponding email: amany.mohamed.24@ucl.ac.uk

The introduction of Permitted Development Rights (PDR) in 2013 in England allowed for the conversion of commercial buildings (e.g. offices) for residential use without planning permission. However, such conversions may be potentially associated with negative impacts on indoor environmental performance, such as lack of indoor space, poor air quality, thermal, energy and daylight performance, which could affect the health and wellbeing of occupants. For example, lack of space could have severe negative impacts on occupant health and well- being, highlighting the importance of space standards for achieving basic lifestyle needs. Existing research using energy efficient optimization of building form and layout is based on hypothetical models that do not reflect real world case studies. This paper aims to quantify the extent to which the optimization and prediction of indoor spatial configuration through an Artificial Intelligence (AI) informed approach can improve indoor environmental performance of homes created under PDR. This study optimizes the floor plan of an office to residential conversion for energy efficiency and daylighting.

POSTERS

A systematic review and meta analysis: how are pathogens distributed in respiratory emissions?

Danny Blundell[1], Catherine J. Noakes[1], Louise Fletcher[1], Martín López-García[1], Marco-Felipe King[1], Waseem Hiwar[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: scdapb@leeds.ac.uk

Pathogen-laden aerosols are the mechanism of choice for a myriad of airborne transmissible diseases and present a significant health risk in the indoor environment. Much has been done to build a picture of the physics, biology, generation, and transport of these bioaerosols in the hopes of mitigating infection risk to those susceptible. However, the initial distribution of pathogens across different respiratory aerosol sizes remains unclear due to the demanding experimental challenges in measuring particle size segregation and working with microorganisms. This problem is further magnified when considering the role played by evaporation in the air and the implications aerosol and droplet sizes have on the transport of the pathogens to susceptible people. The systematic review aimed to extract and collate data from the current literature to answer the question: "What is the concentration of pathogens throughout the range of aerosol sizes produced in respiratory emissions?" The review employed a systematic methodology, as laid out by PRISMA, to identify and examine the experimental methods capable of measuring aerosol size segregation and the quantity of pathogens/microorganisms present across different sizes released during respiratory activities. The systematic review collated 55 papers from an initial 1247, reporting on a myriad of experiments utilising a range of different sampling techniques to measure data on pathogen concentration in human exhaled breath. To combine and quantify these findings, a meta- analysis on experiments used to quantify SARS-COV-2 and mycobacterium tuberculosis is now being conducted. Initial results support the hypothesis that pathogens tend to be more concentrated in smaller aerosols and suggest that pathogens are not distributed by a constant concentration by aerosol volume. This has important implications for modelling exposure using tools such as computational fluid dynamics, as a distribution by volume is the current assumption made by most studies.

A CFD shower model as a tool to assess inhalation risk from shower design.

Amber Brennan[1], Catherine J. Noakes[1], Nikil Kapur[1], Duncan Borman[1], Emma Tidswell[1], Ginny Moore[2]

[1]University of Leeds, Leeds, UK.
[2]UK Health Security Agency, Salisbury, UK.
Corresponding email: A.J.Brennan@leeds.ac.uk

Typical showerheads have an average flow rate of 10-15 L/min and can generate respirable- sized water droplets which can contain microorganisms. Inhalation of contaminated water droplets have been linked to infections caused by bacteria such as Legionella pneumophila and non-tuberculosis mycobacteria (NTM).

To achieve carbon neutrality, water and energy are connected. Water saving showerheads reduce water and energy consumption by reducing flow rates and sometimes introducing water aeration, with some water-stressed areas mandating use of these devices. Published data suggests these devices achieve higher droplet velocities than more traditional designs, resulting in higher aerosol concentrations. It is not clear if this corresponds to increased bio-aerosol concentrations and general droplet distribution patterns in showers are not well understood. Therefore, there are concerns both around net-zero and public health in terms of shower design.

This study developed a novel CFD model to simulate water droplet breakup in an occupied shower, validated by both experimental particle measurement and published literature to show shower air, water and particle behaviour. The model enables the flow rate and shower- head nozzle size to be adjusted and related to generation of aerosol particles so that shower designs can consider both energy and health in tandem.

The model results show similar quantitative and visual representation to published literature, and particle generation aligns to experimental trends. User location and water impact point relative to showerhead position affects both flow dynamics and the number of particles observed. There is a temperature dependency, with hot water generating higher aerosol concentrations, and both the CFD and experimental data suggest that a smaller nozzle diameter is likely to result in more inhalable particles. The results suggest that shower design changes should be selected and managed in terms of public health, specifically for high-risk environments with a focus on production of aerosols to minimise exposure risk.

HEALTHY BUILDINGS NETWORK LEEDS

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Modelling human behaviour in crowds: A visually guided approach and an application to structural engineering.

Samuel Curtis[1], Mateusz Bocian[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: vdft5519@leeds.ac.uk

The realistic simulation of crowds is of great importance to the design of safe structures and urban environments. Within structural engineering, crowd behaviour is often overlooked when considering the dynamics of structures such as floors and bridges which are designed to carry human traffic. Predicting the vibration response of lightweight, slender structures to crowds has been an active area of study since the closure of the London Millennium Bridge in 2000 due to uncomfortable vibrations under crowded conditions. There are still gaps in the knowledge in this area, including the exact extent to which gait synchronisation plays a part in causing instability.

In this poster we examine an agent-based approach to crowd simulation originally proposed by Moussaïd et al. which aims to model human behaviour realistically through vision-based decision making. The model has pedestrians adapt their direction and speed based on a simple procedure fed by visual information.

We first outline the procedure and observe its effectiveness at reproducing real-world behaviours compared to other approaches. We review a modification to the model which includes the desire of some pedestrians to maintain cohesive 'social groups'. This is relevant to human-structure interaction as there is evidence that such groups are more likely to synchronise their footsteps.

Finally, we set out a broader aim of this PhD project: to apply this model to the problem of predicting the dynamic response of structures to crowds of pedestrians.

HEALTHY BUILDINGS NETWORK LEEDS

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Inequities in PM2.5 exposure and respiratory health: evidence from micro-level data in China.

Jingyuan Di[1], Laura Marsiliani[2], Thomas Renstrom[2]

[1]*University of Leeds, Leeds, UK.*
[2]*Durham University, Durham, UK.*
Corresponding email: j.di@leeds.ac.uk

Air pollution, both outdoor and indoor, poses significant risks to human health. To better understand these risks, this study quantifies individual-level PM2.5 exposure and investigates how exposure, income, and demographic factors affect respiratory health outcomes in China. Using micro-level health and demographic data from the China Health and Retirement Longitudinal Study (CHARLS) merged with official city-level air pollution records, we estimate indoor PM2.5 concentrations using a Mass Balance approach and subsequently calculate individual exposure levels.

We analyse the relationship between respiratory health status, PM2.5 exposure, and socioeconomic indicators, highlighting disparities based on gender, income, and region. Probit regression models estimate the impact of PM2.5 exposure and socioeconomic status on respiratory health under two scenarios: windows closed and windows open. The consistency of results across these two scenarios underscores the robustness of our findings, showing poorer respiratory health to be significantly associated with higher PM2.5 exposure and lower socioeconomic status, aligning with previous literature. However, exposure estimation in this study considers only two indoor concentration sources -cooking fuel and smoking combustion in living areas- while workplace exposure is not accounted for. This limitation is reasonable given that most individuals in the dataset are retired.

These results underscore the potential individual health gains from both reductions in ambient air pollution and improvements in household air quality, such as better ventilation practices and transitions to cleaner cooking fuels.

Vision-based personal thermal comfort assessment in the built environment.

Salma ElBahy[1,2], Amit Kant Kaushik[1], Roziana Ramli[1], Wai Lok Woo[1]

[1]Northumbria University, Newcastle, UK.
[2]Cairo University, Cairo, Egypt.
Corresponding email: salma.elbahy@northumbria.ac.uk

Thermal comfort assessment is essential for occupant's well-being and productivity in indoor spaces. Personal Thermal Comfort (PTC) assessment ensures the precise adjustment of micro-environmental conditions to reduce unnecessary energy uses for space heating or cooling. The assessment basically employs intrusive and distracting methods, such as point-in-time surveys and contact physiological sensors. Vision-based personal thermal comfort assessment is a promising approach to non-intrusively predict personal thermal sensation using thermography, computer vision, and machine learning. However, the literature doesn't present a comprehensive theoretical structure of an assessment model that considers various personal and environmental factors. Studies show contradictions in the variables' significance, data extraction, and analysis techniques. Moreover, they overlook the requirements and considerations for the model's long-term deployment and enhancement for real-world applications. The study presents a two-phase conceptual framework for vision-based PTC assessment considering personal factors (age, gender, clothing and activity detection), and environmental factors (indoor and outdoor conditions). The framework draws attention to the need for a third phase that reflects key principles for successful model deployment within the digital twin frameworks for smart buildings. The research analyses the current research trends and discusses the considerations and limitations within each phase. The framework is an initial methodology design for future empirical studies to develop an assessment tool for personal thermal comfort. The tool integration into smart building systems develops dynamic performance for different implementation scenarios of occupant-centered automation.

HEALTHY BUILDINGS NETWORK LEEDS
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A case study evaluation of longitudinal indoor air quality in a UK Passivhaus.

Martin Fletcher[1], Kate Morland[1], Jim Parker[1], Felix Thomas[1], Mark Collett[1]

[1]Leeds Beckett University, Leeds, UK.
Corresponding email: M.F.Fletcher@leedsbeckett.ac.uk

The Passivhaus Standard is the foremost sustainable building performance standard. Passivhaus buildings apply a fabric-first approach, combining highly efficient materials with airtight design to reduce thermal losses, with ventilation provided mechanically with heat recovery (MVHR). Although evidence indicates that Passivhaus dwellings provide excellent thermal performance, comparatively less is known about the long-term performance of their ventilation systems.

This research presents the results of a 12-month indoor air quality (IAQ) monitoring campaign in a 3-bed detached Passivhaus in Northern England. The dwelling received Passivhaus certification in 2015 with research conducted from August 2022 until August 2023, supporting assessment of aged ventilation performance. IAQ monitoring considered Carbon Dioxide (CO2) and Particulate Matter (PM) concentrations at 2-minute intervals in 4 locations (2 internal, 2 external). In addition to monitoring IAQ, the performance of the MVHR system was evaluated with spot-measurement of flow rates at supply and extract vents.

The MVHR system was found to be unbalanced, with extract flow rates >10% higher than intake. 24-hour average CO2 levels were <872 ppm, suggesting good overall IAQ. Peak hourly average CO2 events were all <1500 ppm, with only 23 hours (0.3% total) in the range considered as 'moderate' in CIBSE Guide A. Annual internal PM levels were within DEFRA thresholds, although exceeded the more stringent WHO thresholds. Three peak periods were examined, with internally generated spikes in PM levels found to correlate with cooking or use of the wood-burning stove. Elevated outdoor PM levels were mirrored inside but at a much lower level, indicating filtration by the MVHR system.

Overall, the data indicate good IAQ in the dwelling, with acceptable ventilation provision despite a need for system rebalancing. The findings highlight the benefit of routine MVHR performance tests, whilst also indicating a fair degree of tolerance in the Passivhaus ventilation strategy.

Investigating activity-induced airborne contamination in hospital patient rooms: an integrated experimental and computational approach.

Jiyeong Jung[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: J.Jung@leeds.ac.uk

Airborne transmission of pathogens in hospital patient rooms remains a significant concern for infection prevention and control. While ventilation design and respiratory emissions have been widely studied, less is understood about the transient release and resuspension of bioaerosols associated with routine patient room activities such as bed making, curtain movement, and surface cleaning.

This PhD project investigates activity-induced airborne contamination through an integrated experimental and computational approach. The research involves controlled chamber experiments that replicate realistic care scenarios under mechanical ventilation. Each activity will be tested individually under varying ventilation, with repeated trials to capture both the generation and post-activity decay of airborne contaminants. Particle concentrations and viable microbial content will be measured using optical particle counters and microbial air samplers to assess spatial and temporal dispersion patterns.

In parallel, Computational Fluid Dynamics (CFD) models will be developed to simulate airflow, particle transport, and deposition associated with these activities. Turbulence effects will be explored using appropriate modelling approaches, and CFD predictions will be validated against the experimental data. Particular emphasis will be placed on particle size distributions relevant to viable pathogen transport and occupant exposure risk.

This dual-method approach aims to clarify the physical mechanisms behind short-term airborne contamination and identify high-risk care activities that may require mitigation through targeted ventilation or procedural adjustments. The project contributes to the HumanIC network’s objective of improving hospital environmental safety through human-centric indoor climate design, as part of a Marie Sklodowska-Curie funded doctoral programme.

Currently in its early stage, the project focuses on literature review, formulation of research questions, CFD model setup, and experimental protocol development. The outcomes are expected to support the development of evidence-based, activity-specific infection control and ventilation strategies in healthcare environments.

HEALTHY BUILDINGS NETWORK LEEDS

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Assessing the placement of HEPA air cleaners in a multi-zone hospital ward to reduce infection risk.

Anushi Khandare[1], Alexander Edwards[2], Catherine J. Noakes[1], Martín López-García[1], Louise Fletcher[1], Marco-Felipe King[1], Andrew Carnegie[3]

[1]University of Leeds, Leeds, UK.
[2]University of Bristol, Bristol, UK.
[3]Air Sentry Limited, Unit 1, Great Somerford, Wiltshire, UK
Corresponding email: pmank@leeds.ac.uk

The COVID-19 pandemic has emphasised the need for understanding the dynamics of airborne infections and good ventilation, particularly in a hospital. When deployed safely and maintained well, air cleaners are an important advancement in mitigating against indoor air pollution and infection transmission, especially where increasing ventilation is challenging. This work investigates the impact of air cleaners on reducing the concentration of airborne pathogens in a multi-zone naturally ventilated hospital ward using CONTAM modelling. The methodology and the ward design were based on prior work on ventilation by Edwards et al. [2023]. The model assumed HEPA-based air cleaners were strategically placed at different locations in the hospital ward zones with an infectious person moving between spaces. Simulations analysed fluctuations in pathogen concentration and occupant exposure over an 8-hour period. The reduction in concentration was strongly influenced by the location of air cleaners relative to the pathogen source and the ventilation pattern along with spatial arrangement of each zone. Results demonstrate air cleaners can significantly reduce airborne pathogen concentrations, but where the location of an infectious person is changing or uncertain, more devices may be needed. The model provides useful insights for designing multi-zone wards to minimize airborne transmission and improve safety for healthcare workers and patients. CONTAM is effective for exploring zonal flows and time fluctuations. However, as the model focuses on bulk flow, validating the results with experimental data, and detailed analysis of airflow patterns using computational fluid dynamics to explore spatial variations will form the basis of future work.

The impact of home energy efficiency measures on children's respiratory health: A scoping review.

Richa Kulkarni,[1] Eleanor Harrison,[1] Freya F Semple,[1,2] Abigail Whitehouse,[3,4] Tom Clemens,[5] Olivia V Swann[1,6]

1. Centre for Medical Informatics, Usher Institute, University of Edinburgh, UK
2. School of Medicine, Dentistry & Nursing, University of Glasgow, UK
3. Centre for Genomics and Child Health, Queen Mary University of London, Barts and The London School of Medicine and Dentistry, London, UK
4. Paediatric Respiratory Department, Royal London Hospital, Barts Health NHS Trust, London, UK
5. School of Geosciences, University of Edinburgh, Edinburgh, UK
6. Department of Child Life and Health, University of Edinburgh, UK

Background: Amid rising fuel poverty and an inefficient housing stock, the UK is facing an energy efficiency crisis. Home energy efficiency (HEE) measures - such as insulation, double glazing, and heating upgrades - are key to achieving the UK's Net Zero targets. However, while these measures improve thermal comfort and reduce emissions, they may inadvertently compromise indoor air quality, and consequently, respiratory health.

Objective: Given children's increased vulnerability to poor home environments due to their developing respiratory systems, this scoping review aims to investigate how HEE measures impact respiratory outcomes in children under 18.

Methods: A systematic search was conducted across four electronic databases to identify relevant primary research studies. Eligible studies included interventional and observational designs evaluating HEE measures and reporting respiratory outcomes (e.g., asthma, bronchitis, wheeze) in a paediatric population. Studies were screened independently by two reviewers, and data were extracted using a pre-defined template to collate, summarise, and narratively synthesise the findings.

Results: A total of twenty-three studies met the inclusion criteria, all conducted in high-income settings, with notable representation from the USA and UK. Thirteen studies focused on low-income households experiencing energy poverty and substandard housing. Heating upgrades (n=13) and insulation (n=10) were most frequently assessed. Eleven of the included studies evaluated broad, multi-component housing improvement programmes, in which HEE measures were only one element, limiting the ability to isolate the effects of HEE measures alone. Nonetheless, 96% of studies reported improved respiratory outcomes, including reductions in asthma symptoms and hospital admissions. 57% of studies discovered associations with reduced indoor pollutant concentrations, including dampness and mould. Evidence from low-income settings remains limited, and study heterogeneity posed challenges for comparison.

Conclusion: HEE measures show promise in improving respiratory health within children. However, further research is needed to isolate their effects and expand evidence across more diverse settings. Findings from this review can guide policymakers towards balanced, health-conscious retrofit strategies.

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Impacts of indoor high temperature on cardiovascular health among community-dwelling adults: a scoping review.

Jianying Liao[1], Nibedita Ray-Bennett[1], Joshua Vande Hey[1], Liu Yang[1,2], Yutong Samuel Cai[1,3]

[1]University of Leicester, Leicester, UK.
[2]Shanxi University, Shanxi, China.
[3]Leicester General Hospital, Leicester, UK.
Corresponding email: jl896@leicester.ac.uk

Study's purpose. As global temperature rises, the frequency and intensity of heatwaves have increased, posing significant health risks, particularly for individuals with cardiovascular diseases (CVDs). Given that people spend the majority of their time indoors, high indoor temperature may exacerbate heat-related cardiovascular responses. This scoping review aimed to map the existing evidence on the impacts of high indoor temperature on CVD outcomes, including hypertension, symptom reporting, hospitalisation, and mortality.

Methods. A comprehensive literature search was conducted across PubMed, Medline, and Web of Science to identify studies published between January 2014 and December 2024. Following the Joanna Briggs Institute (JBI) scoping review framework, eligible studies were screened and data extracted based on study design, exposure assessment, population characteristics, and reported cardiovascular outcomes.

Results. Fifteen studies met the inclusion criteria, with most focusing on older adults (average age ranged from 36.3 to 79.6 years) and employing cross-sectional designs. Key findings indicated an inverse relationship between indoor temperature and blood pressure, particularly in colder periods. However, limited studies examined the effects of high indoor temperature, with mixed results regarding CVD outcomes such as emergency visits and blood pressure variability. No studies directly investigated the relationship between high indoor temperature and cardiovascular mortality. Methodological limitations, including heterogeneous exposure assessment and insufficient adjustment for confounders such as humidity and air pollution, were prevalent.

Discussion and conclusion. Current evidence remains insufficient to understand the adverse impacts of high indoor temperature on cardiovascular health. In the context of global warming, further research is warranted to better understand broader cardiovascular health risks of high indoor temperature, particularly among younger populations. Future studies should adopt robust study design, improve exposure assessment, and consider both environmental and behavioural factors to strengthen the evidence base for policy interventions.

HEALTHY BUILDINGS NETWORK LEEDS

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Reimagining air quality communication: Culturally inclusive formats and strategies for engaging diverse populations.

Emma Lonnia[1], Douglas D. Booker[1] and Marco-Felipe King[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: vcnc9201@leeds.ac.uk

Air pollution is a major public health issue in the UK, contributing to an estimated 43,000 deaths annually. However, impacts are not equally distributed. Ethnic minority groups are disproportionately affected due to historical migration patterns, socioeconomic inequality and structural discrimination in housing - factors that increase exposure to harmful pollutants. Some communities also face increased vulnerability due to a higher prevalence of pre-existing health conditions, such as asthma, diabetes and cardiovascular disease, which amplify the severity of air pollution-related outcomes.

Effective air quality communication is essential to help individuals reduce exposure and protect their health. Yet current formats often fail to engage many UK communities due to barriers including language, digital exclusion, mistrust of institutions and cultural differences in risk perception. This study explores how air quality communication can be improved through culturally tailored formats and delivery strategies that support equitable access to environmental health information and promote behavioural change in populations underserved by existing approaches.

The objectives are to:

- Explore how air quality is communicated outside the UK;
- Evaluate current UK communication formats in terms of comprehension, engagement, and actionability;
- Identify cultural barriers to effective communication;
- Compare communication needs across cultural groups;
- Explore subgroup-specific needs, such as those relating to age, gender or ability;
- Co-design digital and non-digital air quality communication formats and delivery strategies based on participant insights;
- Gather feedback on the new formats to assess effectiveness in addressing cultural barriers and improving engagement.

The study follows a three-phase approach. Phase 1 (underway) involves collecting qualitative data via questionnaires from 24 participants across 19 countries, including long-term UK residents and recent migrants. Phase 2 will use these insights to co-design two communication formats (one digital and one non-digital) along with delivery recommendations. The design process is guided by principles of universal design, co-production and design justice to ensure outputs are accessible and community informed. In Phase 3, participant feedback on the new formats will be analysed to assess effectiveness and guide further refinement.

Anticipated outcomes include practical, inclusive communication tools that can enhance public health messaging and improve engagement with air quality information in diverse UK communities.

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Optimal occupant density for minimizing indoor airborne transmission risk from the perspective of integrated short- and long-range airborne route.

Xiaowei Lyu[1], Zhiwen Luo[2], Emmanuel Essah[1]

[1]University of Reading, Reading, UK.
[2]Cardiff University, Cardiff, UK.
Corresponding email: xiaowei.lyu@pgr.reading.ac.uk

Previous studies often treated distance and ventilation as two independent control measures for short- and long-range airborne transmission, respectively. However, by linking short- and long-range airborne transmission through an integrated model, we found that ventilation and distance can continuously and interactively influence airborne transmission. Moreover, these two measures can be further connected through occupant density, since increasing occupant density can simultaneously increase ventilation and decrease interpersonal distance. This finding highlights the importance of reconsidering occupant density's role in airborne transmission control. One of the most important research questions is whether there exists an optimal occupant density that can minimize airborne transmission indoors, given that the changes in ventilation and distance driven by occupant density have opposing effects on airborne transmission. By integrating the short- and long-range continuum with ventilation-distance dynamics, our study identified an optimal occupant density that minimizes airborne transmission, which is highly sensitive to space area and per-person ventilation rates but less influenced by factors such as respiratory activity, physical movement, or exposure time. Further incorporating our approach into ASHRAE Ventilation Standard 62.1, we found that transmission risk can be significantly reduced by adopting an optimal occupant density rather than a default one, particularly in spaces with high physical activity, such as cafeterias, where the risk can be reduced by up to 30%. Overall, our findings underscore the critical role of occupant density in airborne transmission. Because current standards primarily focus on managing ventilation rates, optimizing occupant density presents a valuable opportunity to enhance existing ventilation standards and further mitigate airborne transmission risks.

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Characterising passenger contact behaviour on public transport: implications for respiratory disease transmission risk.

Xiaoxuan Qin[1], Martín López-García[1], Marco-Felipe King[1]

[1]University of Leeds, Leeds, UK.
Corresponding email: X.Qin@leeds.ac.uk

Purpose. This study investigates passenger contact behaviour on public transport to understand the potential transmission of respiratory diseases such as SARS-CoV-2. By quantifying contact patterns, seat preferences, and surface interactions, we aim to inform public health strategies for reducing infection risks in shared transit environments.

Methods. Observational data were collected via CCTV footage from a single-decker bus in Newcastle, capturing daytime journeys. We analysed the seat selection patterns of 257 passengers and documented the surface contact behaviours of 145 passengers. Contact events were categorised by journey sections (boarding, seated, alighting), contact surfaces (poles, handles, headrests), hand used (left/right), and whether facial membrane contact followed. Seat preferences were analysed in relation to bus occupancy, row position, and adjacent seating status. Statistical analyses included ANOVA and LOESS regression.

Results. Seat selection analysis revealed significant preferences for specific locations, with row position ($p=0.00205$) and window/aisle preference ($p=0.01637$) emerging as significant factors. At lower occupancy (< 15 passengers), over 50% chose window seats and avoided sitting adjacent to others. Contact frequency varied significantly by journey sections ($p<2e-16$), with seated, alighting>boarding. Surface contact increased with row number, with row 7 showing the highest increase (coefficient=0.31423, $p = 1.37e-06$). Right-side poles had the highest contact frequency, while handles were contacted less frequently. Facial membrane contacts occurred predominantly during the seated section, with no hand preference observed for surface contacts ($p=0.169$).

Conclusion. Our findings reveal distinct patterns in passenger behaviour that could influence pathogen transmission risk on public transport. The identification of high-contact surfaces and preferred seating locations provides valuable data for targeted intervention strategies. These results are being incorporated into Quantitative Microbial Risk Assessment (QMRA) models to estimate infection risk scenarios and evaluate potential mitigation measures, contributing to safer public transport design and operation in the context of respiratory disease management.

Evolution of volatile organic compounds and their health risks following the opening of a newly built office building.

Thiphanie Riveron[1], Anna L. Hansell[1,2], Rebecca L. Cordell[1,2]

[1]University of Leicester, Leicester, UK.
[2]Leicester General Hospital, Leicester, UK.
Corresponding email: tpr7@leicester.ac.uk

Little is known about the time profile of volatile organic compound (VOC) concentrations in newly built office buildings. Several studies conducted in private buildings have shown that high concentrations of VOCs are present during and shortly after construction, which then decrease over the next few months to reach lower and more stable concentrations. In this study, VOCs were sampled in four rooms of a newly built office building over the 15 months following its opening. The samples were analysed by comprehensive two-dimensional gas chromatography with dual flame ionisation detection and mass spectrometry. The study found high but fluctuating concentrations of VOCs, with a maximum TVOC concentration reaching 1492 μgm^{-3} in one office, one month after the opening. After six months, the TVOC concentration reduced by 60 to 76% and reached stable concentrations under 200 μgm^{-3} in all the rooms. VOC concentrations and composition between rooms were impacted by the number of occupants and the position of the offices inside the building. To determine health impacts, hazard quotients (HQ) and cancer risks (CR) were calculated using the US Environmental Protection Agency (US EPA) reference values for inhalation exposures. At the end of the sampling period, all the HQs were under 1, suggesting that exposure to non-carcinogenic VOCs should not impact the health of the building's workers. CRs were between 1E-04 and 1E-06, which the US EPA identifies as providing possible risk from long-term exposure. More studies are needed to characterise VOC exposures and their potential risks to the occupants of newly built public buildings.

A relational approach to indoor air: Exploring household composition and indoor air in fuel-poor homes.

Rebecca Sale[1], Lucie Middlemiss[1], James B. McQuaid[1], Catherine J. Noakes[1], Marco-Felipe King1[1], Beverley Searle[1], Merel Stevens[2]

[1]University of Leeds, Leeds, UK.
[2]Erasmus University Medical Center, Rotterdam, Netherlands
Corresponding email: ee21res@leeds.ac.uk

Practices in the home, including cooking, bathing, and heating can influence temperature, humidity and CO2 in households. Managing these indoor air parameters is important for thermal comfort, good air quality and suitable air for breathing. Households living in fuel poverty might struggle to regulate these parameters. For example, it can be difficult for fuel-poor households to balance maintaining heat in the home, while also adequately ventilating without losing heat. Cold, moist environments with poor ventilation can increase the likelihood of damp and mould and this is worsened when homes are underheated and poorly insulated. Living with poor indoor air, as well as living in fuel poverty, can have negative impacts on physical and mental health, particularly for children. So, while it is understood that fuel poor households might experience poor indoor air, it is unclear how different household compositions experience and manage indoor air in their homes, or whether certain household types (e.g. households with children) are differentially affected.

Indoor air research is dominated by quantitative methods, however taking a hybrid approach to air quality science, that considers both physical and social science, can produce a more rounded understanding of indoor air in homes that reveals socio-cultural meanings of air. Therefore, this research aims to investigate indoor air in homes in a hybrid way, by using a Relational Approach to analyse interviews, surveys and indoor sensor data from fuel-poor households in Valencia (Spain), Obuda (Hungary), Jelgava (Latvia) and Edirne (Turkey) who were part of the WELLBASED project. A Relational Approach is used in this project to investigate how different household compositions, and thus the way that people live with others in their homes, shape the experience and management of indoor air in fuel-poor homes.

Preliminary quantitative analysis suggests that levels of CO2, humidity and temperature over a three-month winter period vary between household compositions. For example, In Valencia, single adult households with children experienced the lowest average temperatures throughout the day over a three-month winter period, compared to other household types. Initial interview analysis suggests that the management of damp and mould is shaped by relations of care for children, or by standards people want to uphold for visitors and friends.

The impact of indoor air quality and heat on children and young people's health: a linked data approach.

Niloofar Shoari[1], Rich Fry[2], Douglas Booker[3], Catherine J. Noakes[3], Yair Schwartz[1], Daniel Godoy-Shimizu[1], Ivan Korolija[1], Henry Burridge[4], Mark Mon-Williams[3], Dejan Mumovic[1], Pia Hardelid[1]

[1]University College London, London, UK.
[2]Swansea University, Swansea, UK.
[3]University of Leeds, Leeds, UK.
[4]Imperial College London, London, UK.
Corresponding email: n.shoari@ucl.ac.uk

Children and young people (CYP) spend an average of 32.5 hours per week in school, making these environments critical to their health and educational outcomes. Improving school environments presents a unique opportunity to promote health and equity for all children.

The Child And Adolescent Health Impacts Of Learning Indoor Environments Under Net Zero: (CHILI) Hub aims to advance understanding of how school building environments affect CYP's health by combining detailed school building data with national health and education records.

In this presentation, we will outline our approach, which leverages the Modelling Platform for Schools (MPS) to generate and validate thermal and air quality models of school buildings. MPS integrates data from sources such as the Ordnance Survey (OS), Condition Data Collection (CDC), SAMHE indoor air quality data and Display Energy Certificates (DEC). These school buildings data will be linked to national, individual-level, administrative data on children's health and education, including ECHILD, Kids' Environment and Health Cohort (England) and the SAIL Databank (Wales).

Further we will explore the impact of High Efficiency Particulate Air (HEPA) filter installation and use in primary school on children's health and education outcomes. This analysis will link data on use and functioning of HEPA filters the HEPA-ACT trial with primary and secondary care records and education data via the Connected Bradford regional administrative data resource.

We will present our proposed methodology, outcomes and expected challenges, emphasizing how linking multiple datasets allows for a comprehensive analysis of school environments, pupil demographics, and health indicators while accounting for geographical and socioeconomic variations. Our findings will inform policies and interventions to create healthier, more equitable learning spaces for all children.

The Homes, Heat and Healthy Kids Study: The role of underheated homes in preschool respiratory infections.

Olivia Swann[1], Pia Hardelid[2], Chris Dibben[1], **Eleanor Harrison**[1], Ruth Doherty[1], Steve Cunningham[1], Tom Clemens[1], Vittal Katikireddi[3], Duncan Lee[3], Ian Hamilton[4], Russell Viner[2], Jonathon Taylor[5], Aziz Sheikh[6]

[1]University of Edinburgh, Edinburgh, UK.
[2]UCL Great Ormond Street Institute of Child Health, London, UK
[3]University of Glasgow, Glasgow, UK.
[4]University College London, London, UK.
[5]University of Tampere, Tampere, Finland.
[6]University of Oxford, Oxford, UK.
Corresponding email: Olivia.Swann@ed.ac.uk

BACKGROUND. Preschool children spend a lot of time at home when their lungs are developing. Acute respiratory infections (ARIs) are the main cause of hospitalisations in preschool children and are associated with cold, damp housing. Preschool ARIs have lifelong health consequences.

Half of Scotland's housing has low energy efficiency. The Scottish Government is retrofitting housing to increase home energy efficiency (HEE) for Net Zero targets. However, whilst making homes warmer, some HEE measures reduce ventilation, decreasing heat loss but trapping air pollutants indoors, potentially worsening respiratory health.

We can now link children's healthcare data with every home they have lived in across Scotland. This new national linkage will allow us to investigate how underheated homes and the different approaches to warming them affect preschool ARI risk.

OBJECTIVES. 1. Identify children living in underheated homes using routinely collected data. 2. Estimate how many preschool ARIs are due to underheated, damp homes. 3. Explore whether different ways of making homes warmer increase or decrease preschool ARI risk.

PLANNED METHODS. We have established a retrospective birth cohort of children born in Scotland from 2008-2025 followed up until 5 years old. The cohort links cross-sectoral data from healthcare, housing, HEE measures, smart meters, air pollution, high street banking and weather for 4 million child-years and 230,000 properties across Scotland.

Risk prediction models will identify underheated homes using routine data and we will estimate the contribution of underheated homes to preschool ARIs using causal epidemiology methods. We will use machine learning approaches and natural experiment methodology to determine the effects of different HEE measures on preschool ARI risk.

IMPACT. Results will inform energy, welfare, climate and building policies and ensure that Net Zero policies do not worsen health inequalities. The new methodology developed will be applicable to other health conditions, demographics and populations.

Evaluating environmental and building factors affecting plant-based CO2 reduction in indoor spaces.

Xuan Tian[1], Shen Wei[1], Anna Mavrogianni[1], Wei Yu[2], Lan Pan[3]

[1]University College London, London, UK.
[2]Chongqing University, Chogging, China.
[3]South China Agricultural University, Canton, China.
Corresponding email: xuan.tian.21@ucl.ac.uk

CO2 is a crucial indoor air quality indicator, directly affecting occupant wellbeing and cognitive performance. Insufficient ventilation can lead to CO2 accumulation, contributing to occupant discomfort, fatigue, and reduced productivity. Indoor plants offer a nature-based strategy for air purification, absorbing CO2 through photosynthesis while also influencing humidity levels via evapotranspiration. While many studies have demonstrated the ability of plants to absorb CO2 under controlled laboratory settings, real-world environments present additional challenges. Indoor spaces are influenced by a complex interplay of building design, ventilation dynamics, and environmental conditions, making it difficult to predict how plants will perform outside laboratory chambers. Existing research has primarily assessed overall CO2 removal in field settings but has not systematically investigated the role of surrounding environmental and building-related factors in shaping plant effectiveness.

This study experimentally investigated the influence of multiple environmental and building-related factors on CO2 absorption by plants. Ficus elastica (rubber fig) was tested in a controlled indoor environment under different conditions, including variations in plant quantity, placement, room airtightness, airflow, initial CO2 concentration, continuous CO2 sources, lighting conditions, temperature, and humidity. Each factor was isolated and evaluated over a 24-hour period (12-hour light/dark cycle) to determine its impact on CO2 reduction. The findings revealed that plant-based CO2 removal is highly dependent on environmental parameters rather than plant placement alone. Increased green coverage, higher initial CO2 levels, optimal light exposure, and higher humidity created conditions that enhanced CO2 uptake, while factors such as typical indoor temperature ranges and airflow had a negligible influence. Additionally, the presence of plants led to a noticeable increase in humidity, which may contribute to thermal comfort depending on environmental conditions. These insights highlight the need to optimize environmental conditions when integrating plants into indoor spaces to improve air quality, supporting practical strategies that enhance well-being and work performance.

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Validating the consistency of daylight brightness perception of users in real and virtual environments.

Wentao Zeng[1], Alan Lewis[1], Benjamin Blackwell[1]

[1]University of Manchester, Manchester, UK.
Corresponding email: wentao.zeng@manchester.ac.uk

To explore consistency and differences in daylighting design and research using virtual reality (VR), this study proposed a comparative method of standardised workflows and assessment processes to systematically investigate the effects of real and virtual reality environments with different daylight illumination levels (100Lux, 500Lux, and 1500Lux) on the user's activity performance, perception feedback and physiological responses. A small meeting room at the University of Manchester was chosen as the site for the study. Modelling and daylight simulation based on real scenes through Rhino 3D and ClimateStudio and implanting the scenarios into Unity to create VR daylight environments. The consistency and differences between real and VR daylight environments were analysed by comparing users' performance of reading and recognition tests, affective evaluation (assessing pleasantness, calmness, interest, and excitement), spatial evaluation (assessing brightness, glare, and satisfaction), heart rate response, and qualitative feedback in the two environments at different illumination levels. The study results showed that participants' reading speed and cognitive abilities in VR environments with different illumination levels were not significantly different from the real environment. In addition, the effect of VR on users' perception of pleasure, calmness, interest and satisfaction at different illumination levels was not significant compared to real environments. The study provides empirical evidence that VR can effectively replicate the effects of a real daylight environment on activity performance, perception feedback, and physiological responses under controlled conditions (100-1500 Lux), supporting its application in daylight perception research. The findings provide insights into the validity of VR in simulating daylight environments and its impact on user perception and performance.

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ABOUT
HEALTHY BUILDINGS NETWORK LEEDS

The Healthy Buildings Network Leeds (HBN) is a Horizons Challenge Network from the University of Leeds founded in 2024. It is a pioneering initiative that brings together diverse expertise to transform our built environment into a catalyst for health, well-being, and sustainability.

We strive to create a world where every building supports human health and environmental sustainability, regardless of geographic or economic context. Our motivation is to foster innovative, interdisciplinary research and practical solutions that enhance indoor environments globally.

OUR
MISSION

At HBNLeeds, we believe in the power of collaboration. We unite academics, industry professionals, policymakers, and community leaders to tackle complex challenges in building health. Our work spans multiple disciplines, including:

- Architecture, Design and Engineering
- Public Health and Medicine
- Environmental Science
- Social Sciences, Arts, History and Behavioral Psychology
- Data Science and Technology

Key Focus Areas

1. **Indoor Air Quality**: Developing strategies to ensure clean, fresh air in all indoor spaces.
2. **Thermal Comfort**: Creating environments that maintain optimal temperature and humidity levels.
3. **Lighting, Acoustics & Design**: Enhancing well-being through thoughtful sensory design, integrating cultural and artistic perspectives.
4. **Water Quality:** Ensuring access to clean, safe water in buildings worldwide.
5. **Infection Control:** Designing buildings and mitigations to minimise infection transmission risk.
6. **Sustainable Materials**: Using eco-friendly, non-toxic materials that respect environmental and cultural heritage.
7. **Energy Efficiency**: Designing buildings that minimise environmental impact while maximising health benefits.
8. **Equity and Accessibility**: Ensuring healthy buildings are available to all, regardless of socioeconomic status.
9. **Resilience**: Preparing buildings to withstand and adapt to environmental challenges, disease and climate change.

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Whether you're a researcher, practitioner, policymaker, or simply passionate about creating healthier spaces, there's a place for you in the Healthy Buildings Network. Together, we can reshape our built environment to nurture healthier, more sustainable communities worldwide.

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www.healthybuildingsnetwork.org
healthy_buildings_network@leeds.ac.uk