

## Event 1: Symposium

The symposium brought together a cross-disciplinary group of 89 participants from the fields of health, architecture, engineering and environmental design. The event which took place on 21<sup>st</sup> September 2016 provided a platform for participants to present their latest research findings and knowledge concerning indoor air quality and ventilation in modern airtight homes. Presentations from health, engineering, ventilation, indoor air sciences and architecture communities provided a summary of recent evidence in the field and identified key priorities for research on the [Health Effects of Modern Airtight Housing](#).

It was agreed at the previous steering group meeting that whilst the network may be informed by existing knowledge of schools and offices etc. or by studies of ambient air quality, the focus should be on housing given that total exposure to air pollution is greatest in the home environment.

Presenters were asked to consider:

- What is known, i.e. key problems and challenges related to their specific area of expertise
- What are the current gaps in knowledge? What don't we know? What do we need to know? What is the research question?
- What are the solutions? How do we move forward?

The aim of the day was to establish and refine areas for future research. Prior to the event, a list of key research questions were identified by the committee, to form part of the discussion at the symposium. These questions were presented on a series of A1 posters in the breakout spaces. During the lunch break, participants were asked to identify which questions they believed were most important and which they would like to contribute to. Participants were also given the opportunity to add to the list of key research questions. The outcomes are presented in [Table 1](#).

To collate ideas and feedback to inform future events, a survey was distributed to symposium participants via SurveyMonkey after the event. Responses were received from 30 participants.

Survey questions included the following:

- Overall, how satisfied were you with the symposium event?
- What topics would you most like to learn about or discuss at the follow-up workshop event?
- What outcomes would you like to see from the HEMAC network?
- Who else should be involved in the network?
- Do you have any other comments about the symposium or the HEMAC network?

## Symposium Programme

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10:00	Registration, tea/coffee
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10:30	<b>Tom Inns</b> , <i>Director of the Glasgow School of Art</i> Welcome
10:35	<b>Tim Sharpe</b> , <i>Mackintosh Environmental Architecture Research Unit</i> Welcome and introduction to the network
10:50	<b>Anthony Seaton</b> , <i>University of Aberdeen</i> The air and how the body reacts to it
11:20	<b>Raymond Agius</b> , <i>University of Manchester</i> Ill-health related to air contaminants

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11:50	Tea and coffee break
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12:20	<b>Ian Mawditt</b> , <i>Director of Fourwalls, Bristol</i> The state of ventilation in the UK
12:40	<b>Sani Dimitroulopoulou</b> , <i>UKIEG and Public Health England</i> Healthy indoor environments: Challenges for Policymakers

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13:00	Lunch break
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14:00	<b>Mich Swainson</b> , <i>BRE, Watford</i> Observed effects of poor ventilation in modern homes
14:20	<b>Atze Boerstra</b> , <i>Director of BBA Binnenmilieu, The Netherlands</i> Residential ventilation, health, comfort and control: the NL experience
14:40	<b>Pawel Wargocki</b> , <i>Technical University of Denmark</i> Links between Ventilation and Health

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15:10	Tea and coffee break
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15:40	<b>Jan Sundell</b> , <i>Tsinghua University Beijing</i> Ventilation in homes and health
16:10	<b>Lynne Sullivan</b> What do designers need to know?
16:30	<b>Discussion</b>

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17:00	Close
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## Speakers

### **Prof Tim Sharpe**

A graduate of Dundee and Strathclyde Universities, Professor Sharpe is an architect with both practice and research experience in a number of fields, including user participation, environmental architecture and low energy design. He co-founded and now directs the Mackintosh Environmental Architecture Research Unit. MEARU was established in 1986 within the Mackintosh School of Architecture and undertakes strategic and applied research into a wide range of aspects of sustainable environmental design, responding to a growing commitment to user-centred, low energy, eco-sensitive architecture in the context of increasing global concerns. Recent work has led to the significant expansion of MEARU, widening its portfolio of expertise to include: health and wellbeing in buildings; indoor air quality; energy efficient refurbishment; and building performance evaluation. Funded projects include building performance evaluation of a range of low energy houses across the UK, and research into ventilation, health and well-being in housing, including work for the Building Standards Directorate. He is an expert evaluator on the Innovate UK Building Performance Evaluation Programme, chair of the NHBC Scottish Technical Committee and member of the national Standards committee and is an expert witness for dampness and construction cases.

### **Prof Anthony Seaton**

Professor Seaton qualified from Cambridge University in 1962 and trained as a junior doctor in Liverpool. After senior posts in respiratory medicine in West Virginia, USA, and Cardiff, he was director of the Institute of Occupational Medicine in Edinburgh from 1978-90. He edited Thorax from 1977-81. From 1988 until he retired in 2003 he was head of the department of Environmental and Occupational Medicine in Aberdeen University. Since retiring, he is emeritus professor at Aberdeen and has rejoined the Institute of Occupational Medicine as an honorary senior consultant. He has published seven books and over 300 papers on respiratory and occupational medicine and other topics. He chaired the UK Government's Expert Panel on Air Quality Standards (EPAQS) and was on the Royal Society's Working Group on nanotechnology. His research interests have been in environmental effects on health, particularly dust and chronic lung disease, air pollution and the heart, diet and the early causation of asthma, and chemicals and chronic neurological disease.

### **Prof Raymond Agius**

Raymond Agius is a Professor of Occupational and Environmental Medicine and Director of the Centre for Occupational and Environmental Health at the University of Manchester. He is also an honorary consultant in two Manchester University Hospital NHS Trusts. His previous workplaces included the Department of Community Medicine at the University of Edinburgh and the Institute of Occupational Medicine. His research interests encompass occupational and environmental ill health ranging from cardio-respiratory disease to psychological stress. He has conducted epidemiologic studies on air pollution in Scotland and elsewhere, as well as in methods of predicting and preventing novel respiratory hazards. He is a Fellow of the Royal Colleges of Physicians of London and of Edinburgh, a Fellow of the Faculty of Occupational Medicine of the Royal College of Physicians of London and an Honorary a Fellow of the Faculty of Occupational Medicine of the Royal College of Physicians of Ireland. He is a Past President of the British Occupational Hygiene Society.

**Ian Mawditt**

Ian is a building researcher, specialising in the field of energy performance and occupant comfort. He is the founding director of Four Walls – an independent building performance and research consultancy based in Bristol. The company specialises in post-construction testing and evaluation; in-use studies of building performance, including energy use analysis, indoor air quality investigations, ventilation effectiveness; and occupant satisfaction studies. Ian's work and field experience help to provide an evidence base for informing building performance standards. He was part of the technical team that supports DCLG in the development of amendments to Part F and Part L of the Building Regulations. He was recently engaged by Innovate UK as an expert evaluator under the Building Performance Evaluation programme, and provided technical guidance for the Retrofit for the Future programme. Ian has also worked with organisations such as the Zero Carbon Hub, the Sustainable and Traditional Buildings Alliance, and the NHBC Foundation supplying strategic and technical support to their research programmes.

**Dr Sani Dimitroulopoulou**

Dr Sani Dimitroulopoulou is a Senior Environmental Scientist within the Air Pollution and Climate Change Group, Environmental Change Department in Public Health England. She is also an Honorary Senior Lecturer at the UCL Bartlett School Environment, Energy and Resources. Her research interests include air pollution related effects on health, exposure assessment to air pollution, based on modelling and monitoring of outdoor and indoor air pollution and ventilation, health impact assessments and development of environmental public health indicators. She has over twenty year experience developed through her PhD at Imperial College, her work at Imperial College and Building Research Establishment in the UK, as well as at the National Centre for Environment and Sustainable Development (Greek Environment Agency) and the University of West Macedonia in Greece. She has published more than 60 peer-reviewed papers in international scientific journals and conferences and more than 50 technical research and consulting reports. She is a member of the Scientific Secretariat for COMEAP (Committee on the Medical Effects of Air Pollutants), Member of the Cross Government Group on Gas Safety and Carbon Monoxide, the Secretary of the UK Indoor Environments Group (UKIEG) and Member of the Executive Committee of MESAEP (Mediterranean Scientific Association of Environmental Protection).

**Dr Michael Swainson**

Michael Swainson is principal engineer in BRE's HVAC Engineering and Building Diagnostics team. He has over 20 years' experience designing and undertaking practical investigations into the performance of heating, ventilation and air conditioning systems within buildings, both laboratory based and on site. Michael is largely responsible for implementation of SAP Appendix Q for ventilation products and heat pumps. He was technical author of the; Installation Guidelines for systems 3 and 4 for the Domestic Ventilation Compliance Guide, supporting documentation to AD-F, NF46, Overheating in new homes, and ZCH Solutions to overheating in homes, Evidence review. his is currently testing MVHRs for PHI listing.

**Dr Atze Boerstra**

Dr. Atze Boerstra is founder and managing director of BBA Indoor Environmental Consultancy, a consultancy company specialised in indoor air quality and thermal comfort based in The Hague. He is a fellow at the Eindhoven University of Technology, REHVA fellow and honorary member of the Dutch chapter of ISIAQ (International Society of Indoor Air Quality and Climate). Atze was recently elected as vice-president of REHVA.

### **Prof Pawel Wargocki**

Assoc. Prof Pawel Wargocki graduated from Warsaw University of Technology with honours in 1990. He received his PhD from the Technical University of Denmark in 1998, where he has been teaching and performing research ever since. He has more than 20 years of experience in research on human requirements in indoor environments. He is internationally known for his seminal work demonstrating that poor indoor environmental quality affects performance of office work and learning. Other work influenced requirements for ventilation and air cleaning. Recent research includes studies on emissions from humans including effects of exposure to CO<sub>2</sub>, on sleep quality and on performance of green buildings. He has collaborated with leading research institutions, universities, and industrial partners around the world such as National University of Singapore, Jiao Tong University in Shanghai, Syracuse Center of Excellence, United Technologies and Google. He was President and is a long-standing board member of the International Society of Indoor Air Quality and Climate (ISIAQ), Vice President of Indoor Air 2008, and Chair of ASHRAE committees. Currently he is the member of ASHRAE's Research Administration Committee. He has received several awards for his work including Rockwool Award for Young Researchers, ASHRAE Ralph Nevins Award, ISIAQ's Yaglou Award and Best Paper Award in Indoor Air. He is the Secretary of Academy of Indoor Air Sciences. Published intensively.

### **Prof Jan Sundell**

Jan Sundell is a Swedish multidisciplinary scientist, with a Master's degree in HVAC engineering from Royal Inst. of Technology, 1969, and a MD degree in environmental medicine from Karolinska Inst (1994). He has been involved in several governmental inquiries, about allergies, and environmental health. He has worked for NKB (the Nordic countries), WHO, and EU about ventilation and health. JS has been professor at the Technical University of Denmark, UT Tyler and now at Tsinghua University and Chongqing University, China. He has led a multitude of multidisciplinary scientific reviews, on indoor air and ventilation, VOCs and health, indoor pets and health, indoor particles and health, but also on breastfeeding and allergies. His primary research focuses is on human exposure to air pollutants and health. He has initialized several large epidemiological studies to examine children's exposure to indoor air pollutants and associated adverse health effects, in Sweden, Bulgaria, Denmark, Texas, South Korea, Taiwan, Singapore and China. His research has resulted in 200 peer-reviewed scientific articles. JS was Editor-in-chief of Indoor Air Journal from 2000-2010 and a founding member of the International Society of indoor Air Quality and climate (ISIAQ) and of the International Academy of Indoor Air Sciences (President 2005-2008). Many scientific Awards, including the highest award in indoor air sciences, "The Pettenkofer Award" 2011.

### **Lynne Sullivan**

Lynne Sullivan is a practising Architect and was founding Partner of sustainableBYdesign, finalists in all three 2010-2012 BRE UK Passivhaus Housing Competitions, specialising in low-energy new and retrofit projects in a range of sectors, including a European funded demonstration project at Thamesmead to Passivhaus Enerphit standard. Previously Lynne was Sustainability Director for 9 years at Broadway Malyan, and for 10 years Associate Director at ECD Architects, where she was co-author and winner of the UK's first government-sponsored Zero CO<sub>2</sub> housing competition. Lynne now acts as a design consultant and collaborator, sits on local and national design review panels, and has authored and chairs a number of policy review and research projects for UK governments and others, including the Expert Panel for the Scottish Government whose report "A Low Carbon Building Standards Strategy for Scotland", first published in 2007, was updated in 2013. She was awarded an OBE for services to Architecture in 2011, chairs the Good Homes Alliance, and is a member of the UK Government's Green Construction Board.

Table 1. Summary of research priorities identified

Health Issues			
<ul style="list-style-type: none"> <li>○ Does ventilation lead to ill-health in housing? If so, what is the interval between exposure and ill-health?</li> <li>○ What are the significant factors? Pollution? Moisture? Temperature? Comfort (does this matter)?</li> <li>○ How can poor health be measured and defined?</li> <li>○ What are the costs of health impacts?</li> <li>○ How to link IAQ with health effects using predictive (processed based) models</li> </ul>			
Pollution	Moisture	Temperature	Comfort
<ul style="list-style-type: none"> <li>○ What are the most significant sources of pollution in homes &amp; what health effects do these lead to?</li> <li>○ Is source control or removal through ventilation better?</li> <li>○ What is known about source control in building materials and how can this knowledge be made available to construction professionals?</li> <li>○ What is the potential exposure to VOCs and HCHO from consumer products and activities?</li> <li>○ What concentrations of indoor air pollutants are typically found in new-build airtight homes and how does this compare to older, draughtier homes?</li> <li>○ Does airtightness and controlled environments protect against external pollutants?</li> </ul>	<ul style="list-style-type: none"> <li>○ How does moisture in buildings affect health?</li> <li>○ What are high / low moisture levels?</li> <li>○ What health problems do they cause?</li> <li>○ What are the potential implications of entropy/ humidity recovery heat exchangers with regards to indoor moisture?</li> <li>○ How might decarbonisation strategies impact on hygrothermal properties of building fabric and what are the potential implications of this?</li> <li>○ What is the causal link between mould and health?</li> <li>○ What evidence is available on the performance of hygroscopic and moisture buffering materials? Can these materials reduce demands on ventilation systems?</li> </ul>	<ul style="list-style-type: none"> <li>○ What are the health impacts of overheating? This includes physiological health, obesity, and related effects, for example, from off-gassing</li> <li>○ Are the benefits of warmer homes outweighed by poor ventilation and increased pollution emissions from higher indoor temperatures?</li> </ul>	<ul style="list-style-type: none"> <li>○ How significant is occupant behaviour on IAQ and how can behaviour be influenced effectively?</li> <li>○ What is the relationship between ventilation performance, IAQ and health status among more vulnerable groups, such as respiratory patients?</li> </ul>

### Policy and legislation

- How can we develop and evaluate IAQ criteria for inclusion in sustainable assessment schemes?
- How do we define good IAQ and how can we monitor/ assess this economically and feasibly in a domestic context?
- Could IAQ criteria be effectively embedded in the RIBA plan of works?
- Are current building regulations relating to ventilation provision being met in practice and are these standards adequate to ensure good IAQ?

### Design of the built environment

- What are the causes of poor ventilation?
- How are ventilation systems performing in new-build airtight homes?
- What is the long term performance of ventilation systems?
- What impact do inadequately maintained ventilation systems have on ventilation rates, noise, electrical consumption and heat recovery efficiency?
- What is an acceptable performance standard for ventilation? How relevant is CO<sub>2</sub>?
- Is social housing at greater risk of poor IAQ?
- What do architects currently know about indoor air quality principals and strategies, and how can they be better informed?
- What are the typical maintenance requirements of MVHR systems and has the market adequately evolved to provide these services?
- Who is ultimately responsible for IAQ in housing projects and how can we assign responsibility of IAQ, to include architects, suppliers, contractors, installers?
- What are the potential psychological impacts of the responsiveness, noise and complexity of technologies to control the indoor environment?
- What are the actual energy savings in homes with MVHR systems where occupants habitually open windows?

### Outcomes

- How can ventilation systems be better designed?
- What are UK building professionals perceptions and experiences towards IAQ and the use of MVHR?
- How do we translate existing knowledge from IAQ sciences to practical design guidelines for built environment professionals?
- How does the choice of ventilation and airtightness standards impact on the indoor microbiome and what are the potential consequences on occupant health?
- How do we improve the design of indoor environmental control strategies & interfaces to promote occupant use and engagement, particularly for ventilation systems?
- How can we improve passive ventilation solutions for increasingly airtight housing?
- How do we convince industry to take source control seriously?
- Is there currently a gap in the market for effective ventilation strategies for airtight dwellings?

## Symposium presentations and discussion

The symposium began with presentations from Prof Anthony Seaton (University of Aberdeen) and Prof Raymond Agius (University of Manchester), which provided an overview of the constituents of air (bacteria, fungi and other pollutants) and common consequences of inhaling these in clinical terms.

Prof Seaton presented evidence of how the body reacts to all inhaled particles as invading organisms, which can increase the population risks of heart attacks, stroke and asthma attacks. Prof Agius demonstrated the importance of outdoor air pollution and provided evidence of the known health risks associated with indoor air pollutants. This included information on the toxic potential of chemicals found in indoor environments.

The discussion that followed highlighted the need for a statutory reporting system (similar to the yellow card system) within the medical profession, to provide evidence of unexpected reactions to consumer products or materials. Issues relating to bio-accumulative pollutants were also discussed; where it was highlighted that investigating the effect of accumulative agents requires long term studies, which can be extremely difficult to get funding for. The complexity of measuring health effects were emphasised, due in part to interactions between physiological and psychological outcomes, chemical interactions, and susceptibility.

Following the coffee break, Ian Mawditt (Fourwalls, Bristol) provided an overview of the state of the art of ventilation in the UK, revealing significant issues regarding poor measured airflow rates in modern dwellings. He noted a number of key research gaps, including whether minimum ventilation guidance is fit for purpose and the need for research to establish the health burden of poor ventilation in UK homes.

Following this, Dr Sani Dimitroulopoulou (Public Health England and UKIEG) emphasised important factors affecting indoor air quality in a home environment and outlined a number of key challenges, including the need for a coordinated approach to built environment policy.

The Q&A session raised some important issues regarding the disconnect between ventilation design and performance, and the “circle of blame” culture between designers, developers, clients and end-users. The need for policymakers to create regulations / mechanisms to protect and advise building occupants was highlighted. It was emphasised that although IAQ standards are available, these provide guidance only (i.e. they are not regulatory and are never measured or enforced). In particular, the significant differences between indoor air quality ‘liability’ in the domestic and non-domestic sectors was highlighted (i.e. in the non-domestic sector someone is responsible where-as in the domestic sector there is not), stressing the need for the joining up of legislation.

After lunch, the theme of liability continued, with Dr Mich Swainson (Building Research Establishment) revealing a rise in court cases in modern housing due to complaints of overheating. He suggested that the architectural profession has lost the art of design for



natural ventilation in dwellings and noted that windows are no longer viewed as part of the 'comfort provision'.

Dr Atze Boerstra gave a European perspective and presented findings from the Netherlands, demonstrating that the observed shortcomings of mechanical ventilation systems are not limited to the UK, suggesting the need for maximum ventilation noise level requirements in the building code and obligatory maintenance requirements for ventilation systems.

Following this, Prof Pawel Wargocki provided an overview of the relationship between ventilation and health, emphasising that although there is general agreement that increasing ventilation rates will reduce IAQ related health outcomes, ventilation is only a modifying factor and should not be used as a panacea for all IAQ problems. He noted that in order to establish an acceptable standard for ventilation, we need to first be aware of the level of exposure to air pollutants indoors and define a suitable standard for IAQ.

Finally, Prof Jan Sundell gave a global perspective and provided an overview of the history of ventilation in homes and health, outlining the significant increase in house dust mite proliferation associated with energy conservation strategies in Sweden, resulting from lower levels of ventilation. He stressed the fundamental need for large scale, multidisciplinary projects in the UK, to address the gap in knowledge on the relationship between ventilation and IAQ on occupant health.

The conference concluded with a presentation from Lynne Sullivan (Sustainable By Design), who explained that architects are currently flying blind in this area and emphasised the need for increased collaboration between architects, health care professionals and indoor air quality researchers to ensure that occupant health and wellbeing is a core priority during the design process.

The discussion session at the end of day touched upon a number of important factors, such as the need for increased consumer awareness, the lack of IAQ studies in the UK (and lack of funding), the unregulated nature of homes, the lack of defined standards for a home environment and the disconnection between health studies and monitoring studies. The lack of evidence on the relationship between IAQ and health was emphasised, particularly in comparison to the availability of data on ambient air quality and health.

On a practical level, a call was made for the development of best practice / design guides to provide information to architects and built environment professionals on source control and ventilation provision in modern airtight homes. The event concluded with a networking dinner.

Key priority research areas were identified:

- Large scale UK study to identify impact of IAQ on occupant health
- Source control and material emissions
- Microorganisms in homes

- Guidance for design and construction professionals
- End-user interactions (noise, awareness, control, occupant perception)
- Review of existing evidence of IAQ in modern airtight homes
- Effectiveness of ventilation systems in practice
- Intervention studies on susceptible groups (such as asthma / COPD patients)
- Relationship between house dust mite and airtightness levels in homes

Presentation slides and further information on the symposium event are available at [www.hemacnetwork.com](http://www.hemacnetwork.com)

## Photos from the symposium event



Networking Lunch



Reid auditorium, Symposium attendees

## Survey Responses

### Topic suggestions for follow-up workshop

- Strategies to improve ventilation regulations and guidance (including commissioning of ventilation technologies), and practical solutions to accommodate air circulation in homes
- Step change in design thinking – should we be designing airtight homes that require mechanical ventilation? Can mechanical ventilation ever be ‘fail-safe’?
- Microbial growth in buildings: health impact, trends, monitoring, effect of building design and occupier activity
- Impact of end-user interaction on indoor air quality
- Development of suitable IAQ metrics and standards for measuring and monitoring IAQ. Quantification of ideal, comfortable, acceptable / unacceptable, dangerous and fatal levels
- Construction material emissions and their impact on health and indoor air quality in airtight buildings
- Development of simple ground rules - What are the key measures to implement into new buildings and main things to avoid?
- Building automation and indoor air quality

### Suggested outcomes from network activities

- Guidance / Code of Practice for architects and building services engineers on the key findings, especially common mistakes to avoid
- Increased public awareness of indoor air quality in homes
- Large scale, collaborative, interdisciplinary, and international bids (real game changers) to address evidence gap
- Investigation of the value, effectiveness and enforcement of regulations and standards
- Simple straightforward guidance, at level suitable to be targeted towards different groups: specifiers, owners, users etc.
- A database of material emissions and case studies of current materials used in low energy buildings
- Establishment of a calibrated assessment scale and methodology for measuring and reporting IAQ problems
- Regulatory change to improve ventilation provision

- A better understanding of the problem
- Quantification of the cost of poor IAQ to the health service and indirect costs to the UK economy

#### The key problem that needs addressed

- Conflict between energy efficiency and sufficient ventilation - Does modern domestic architecture which addresses energy conservation imply risk to the humans in the houses? If so, what are the most likely risks and how may they be prevented?
- The disconnect between academia and practice
- Insufficient evidence (science linking cause and effect such that regulation can be meaningful is limited)
- Lack of funding, particularly for inter-disciplinary studies
- Poor dialogue between regulatory bodies and real world stakeholders
- Lack of understanding and awareness (particularly among residents) of the importance of ventilation and indoor air quality
- Need for IAQ standards (based on maximum pollutant concentrations)
- Inadequate ventilation provision in airtight homes
- Source control
- Lack of action - the 'head in the sand' attitude of professionals about health issues and indoor air quality