Better homes, better air, better health

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RCPCH
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bre

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Event report, UKCIP, University of Oxford

Executive summary

The Better homes, better air, better health event was the first stage of a multi-partner-led discussion to engage the built environment and medical communities – researchers, policymakers and practitioners – in how to improve indoor air quality.

The workshop brought together 62 professionals from across the research, industry, policy and third sector communities. The purpose was to encourage industry and research leaders to think about and inform future action on the solutions and knowledge needs for reducing exposure to air pollution when indoors.

Presentations from industry and academic researchers summarised the current evidence base and concerns on:

- Poor indoor air quality, the health impact and solutions available now.
- The impacts of air pollution outside on the breathed environment indoors.
- The breathed environment indoors.

Delegates were asked to consider and report back on:

- What solutions can be enacted now?
- What solutions do we potentially have, but do not yet know enough about? and
- What knowledge gaps do we have that need research and innovation effort?

The ensuing discussions highlighted that many attendees felt that poor indoor air quality in UK homes was at a scale and magnitude that warranted national-level attention and action. Whilst many ideas for action now and in the future were generated, there were a number of clear actions that require immediate attention:

- Proactive clear communication to the public.
- Act now to reduce high outdoor air pollution levels.
- Conduct nationwide monitoring and pooling of data required for outdoor, outdoor ingress indoors and indoor air pollution.
- Strengthen understanding of the relationship between indoor air pollution, exposure and health impacts.
- Define the economic impact of poor indoor air quality and the health benefits of healthy homes.
- Increase the array of positive solutions to help tackle and reduce indoor air pollution, from changing common domestic practices, reducing pollutant emissions from construction materials and home improvement products through to novel Internet of Things solutions and changes in market products including home insurance and mortgage products.

This report should be referenced as:

ARCC, 2017. (Ed. Turner, B.D.) Better homes, better air, better health: Event report. UKCIP, University of Oxford

Next steps

On behalf of all the event partners, Professor Stephen Holgate and Professor Jonathan Grigg are endeavouring to establish an interdisciplinary Working Party on Indoor Air Quality with a life-course focus, with particular consideration given to the impact of poor indoor air quality on children's health and wellbeing.

The ARCC network and BRE are reviewing, respectively, the research and industry knowledge and capability needs and ideas for action raised at the launch event. We hope that all those reading this document will reflect on how they too might be able to help take forward the suggested ideas for action, many of which can be progressed by existing groups, organisations and individuals now.

Until the Working Party is established, the ARCC network will continue to collate contact details of researchers and practitioners wishing to be part of the community of action, on behalf of all partners. This will enable the next steps for the Working Party and the ideas raised by participants to be communicated, and the community of action initiated and sustained.

Event participants

Firstname	Surname	Organisation
Paul	Ajiboye	CETEC
Julian	Amey	IHEEM
Peter	Bonfield	BRE
Patrick	Bonner	Islington Council
Douglas	Booker	NAQTS
Julian	Brooks	Good Homes Alliance
Adorkor	Bruce-Konuah	Oxford Brookes University
Louise	Clarke	Berkeley Group
Malcolm	Cook	Loughborough University
Thomas	Cox	Saint Gobain UK
Cathy	Crawley	BRE
Derrick	Crump	Indoor Air Quality Consulting Ltd
Andy	Dengel	BRE Environment
Emma	Dewey	Mulalley
Sani	Dimitroulopoulou	Public Health England
Gary	Fuller	King's College London
Leigh	George	Allergy UK
Jonathan	Grigg	Royal College of Paediatrics and Child Health/ Queen Mary University of London
Methela	Haque	Royal College of Physicians
Paul	Harrison	IEH Consulting Ltd
Alexander	Hicks	University of Southampton
Julie	Hogarth	JLL
Stephen	Holgate	Royal College of Physicians / University of Southampton
Lorna	Hughes	Ebbsfleet Development Corporation
Carla	Jones	Allergy UK
Ben	Jones	University of Nottingham
Sara	Kassam	CIBSE
Trevor	Keeling	BuroHappold

Firstname	Surname	Organisation
Colin	King	BRE Wales
Juergen	Koch	4 Green Architecture Ltd.
James	Leaning	Knauf
Paul	Linden	University of Cambridge
Matt	Loxham	University of Southampton
Tudor	Luga	Greengineers
Lilian	Martins	MLM Consulting Engineers
Dan	Maskell	University of Bath
Grainne	McGill	HEMAC network, Glasgow School of Art
Linda	McKeown	BRE
Yasmina	Mikhael	RES Design Long and Partners
Frederic	Nicolas	Dyson
Marialena	Nikolopoulou	University of Kent
Kate	Paxton	Hodkinson Consultancy
Gavin	Phillips	University of Chester
Chris	Pottage	Skanska
Pierre	Royer	Kingfisher
Mike	Short	Telefonica
Stephen	Snow	University of Southampton
Roy	Stansbury	Air Quality Plan
John	Tebbit	Robust Details Limited
Ian	Thomson	Dyson
Gin	Tidridge	B & Q
Namir	Tohala	Well Building Facility Management Ltd
Tariq	Tohala	Well Building Facility Management Ltd
Briony	Turner	ARCC network, UK Climate Impacts Programme
Marcella	Ucci	UK Indoor Environments Group / UCL
Charlotte	Wilberforce	Martha Schwartz Partners
Martin	Williams	King's College London
Alistair	Wilson	Kingfisher
Kathryn	Woolley	Hilson Moran
Bill	Wright	Sustainable Homes
Szilvia	Zakar	Sir Robert McAlpine

Motivation and objectives

In 2016, both the RCP & RCPCH working party report Every breath we take and The Bonfield Review Each home counts recommended taking action to tackle poor indoor air quality.

In October 2016 the ARCC network ran an event in partnership with CIBSE and the IET in response to the publication of the RCP & RCPCH report, Every breath we take. Breathe easy – engineering air quality solutions focused on how the engineering community could help address the UK's air quality challenges.

Following this event, along with publication of the Bonfield Review and in light of the numerous calls to action to tackle indoor air pollution in homes, Professor Stephen Holgate, working party chair of the Every breath we take report asked the ARCC network and BRE to devise a way to bring together the medical and built environment communities to tackle this complex problem. Early discussions included consideration of setting up a formal Working party to bring together the health and built environment communities, focused on:

- Establishing the existing evidence base for the health impacts of poor indoor air quality in homes.
- Identifying the possible solutions and reviewing associated evidence of their effectiveness.
- Identifying emerging knowledge needs.
- Making recommendations for action.

To scope out the appropriate remit and constitution of such a Working party, and to inform future work by built environment and medical leaders in this area, the ARCC network coordinated and produced a workshop on behalf of all the partners. The Better homes, better air, better health event took place on 12 April 2017. It was attended by 62 delegates and aimed to encourage industry and research leaders to think about and inform future action on the solutions and knowledge needs for reducing exposure to air pollution when indoors over occupants' life-course and building lifetimes. This report provides an initial analysis and early synthesis of the discussions.

Summary of evidence

The case for action was set out by Professor Jonathan Grigg and Professor Stephen Holgate, both pointing out that air pollution is already considered one of the leading dangers to children's health and is known to effect people chronically over the life-course. Professor Holgate highlighted that the average person in the UK spends just 8% of their time outside. It is therefore imperative that we strengthen our understanding of the relationship between indoor air pollution and health, particularly the aggregated effects of exposure to pollutants. Delegates were left to ponder the potential health impacts and lack of current knowledge on exposure risk represented by the 'reservoirs of dust' that host an array of consumer product chemicals in our homes.

Peter Bonfield, CEO of BRE and author of the Bonfield Review revealed a clear finding that a large number of vulnerable people have been found to be living in homes which have had improvement works to increase energy efficiency without associated appropriate ventilation. This has resulted in poor air quality, with particular issues of mould and damp, which have negative impacts on residents' health . One of the outcomes he anticipates from this event, and the action it will result in, is information and guidance on what to do and what not to do for those involved in supplying, building, managing and maintaining homes.

Professor Jonathan Grigg outlined the respiratory effects of pollutants, drawing on findings related to formaldehyde exposure and also indoor fungal diversity on asthma. He also mentioned the growing body of evidence that suggests volatile organic compounds, thought to be of microbial origin are also being produced by synthetic building materials. He closed by touching on the role of design of buildings and the urban environment to mitigate the effect of outdoor pollutant ingress.

Dr Marcella Ucci, chair of the UK Indoor Environments Group, emphasised that before looking to the solutions, we need a much more comprehensive understanding of the nature of the problems surrounding the quality of air in homes. There are issues with the quality and availability of data, particularly on indoor exposure levels, dose response relationships on key pollutants and a current over-reliance on proxy measures. Dr Ucci notes that whilst with outdoor air the focus is on source control, with indoor air, the focus is very much on ventilation. She also touched upon the social and economic drivers contributing to the indoor air quality problem, and the current misalignment across stakeholders particularly regarding the perception of risk between public health and built environment professionals.

Dr Andy Dengel, BRE, drew on some of the current solutions, where these are possible within the supply chain and the use of innovation, technology and engineering to help improve indoor air quality.

Dr Gary Fuller from King's College London took us through sources of urban air pollution, particularly PM10 and PM2.5, how air enters but also that buildings exhale which can have an impact on outdoor air pollution, concentrations and flows. Professor Martin Williams, also from King's College London, took us through how policies to help the UK meet its climate change carbon emissions mitigation obligations will change the types of pollutants we see outdoors over the lifetime of much of our housing stock. For instance, incentivising biomass energy production could lead to an increase in exposure to primary PM combustion products, including carcinogens, in the period 2030–3050. However, if air quality and energy efficiency measures are considered together, the Climate Change Act target could provide an opportunity for the biggest air quality and public health improvements since the Clean Air Act of 1956.

Dr Ben Jones, University of Nottingham, took us on a rapid tour of types of ventilation commonly used in homes, and how these can impact on pollutant commuting behaviours in our homes. He closed by stressing that whilst ventilation is a mechanism for mitigating exposure to indoor pollutants, efforts to tackle pollutant source control should be made. Further, the health benefits of ventilation that requires energy to function can be in conflict with energy efficiency efforts.

Dr Paul Harrison took us through the known pollution sources in the home, the factors influencing concentrations and exposure levels, and then on to thinking about the variety of solutions we could be working on now and in the future. Dr Sani Dimitroulopoulou from Public Health England explored common indoor chemical pollutants and made the case that it is prudent to try to improve the indoor air quality in our homes, even if the symptoms are not noticeable. She had a clear message for those involved in the construction of new homes, "build tight and ventilate right". Dr Dimitroulopoulou closed by sharing a number of cross-government and stakeholder activities PHE is involved with, or has initiated, to tackle this issue.

Dr Colin King then provided an overview on what happens to air quality when homes are retrofitted, particularly if there is insufficient or defective insulation, inadequate ventilation rates, issues with sealing joints and internal leaks, defective damp courses and trapped moisture. These all help to create ambient conditions for mould growth, creating unhealthy living conditions.

Professor Paul Linden from the University of Cambridge provided the final research-focused talk, sharing a new Engineering and Physical Sciences Research Council funded project, Managing Air for Green Inner Cities (MAGIC), which seeks to provide solutions to poor air quality for cities of the future that are aiming for a 'zero-zero' goal of no air pollution and no heat-island by 2050.

Slides from all the presentations are available at www.arcc-network.org.uk/better-air

Summary of solutions and knowledge needs

These ideas were put forward through table discussion of delegates. A number of the ideas were also identified, and some set out in greater detail, in the delegates' personal action slips (Annex 1) and solution slips (Annex 2).

Common actions identified included proactive, clear communication to the public and industry, the need to act now to reduce high outdoor air pollution levels. However delegates pointed out that there was no point empowering people with information if they don't have any options to act upon it. There was a balance to be struck between focusing effort on talking to technologists to develop solutions for those able to improve the situation within their own means and ensuring effort is going into 'making normal better', building regulations, tackling the complexity of our existing housing stock, changing pollutant producing/exposure causing domestic practices.

There were a number of areas raised for future research and known knowledge gaps. Underpinning many of these was the lack of robust, longitudinal, shared Indoor Air Quality (IAQ) profiles, associated health consequences and datasets across the national housing stock. There was a clear need identified to conduct nationwide monitoring and pooling of data required for outdoor, outdoor ingress indoors and indoor air pollution.

A large number of ideas and actions were identified that could be taken forward now. Suggestions ranged from changing common domestic practices, reducing pollutant emissions from construction materials and home improvement products through to novel Internet of Things solutions and changes in market products including home insurance and mortgage products.

Among the knowledge gaps identified, delegates consistently raised the need to strengthen understanding of the relationship between indoor air pollution, exposure and health impacts and to be able to define the economic impact of poor indoor air quality and the health benefits of healthy homes

Solutions we can enact now

- **Public health campaigns for greater public awareness** that are easy to understand, educational and encourage behavioural change. Starting with the schools – put indoor environmental quality into the 'complementary studies' curriculum, introducing concepts such as: What is a healthy home? Why can water vapour be an indoor pollutant? What are trickle vents? How can we take more control of what we put into our indoor air?
- **Use 'big data' capabilities** to aggregate data (though we must first ensure data is fit for purpose).

- **Look at the economics of the issues**. Establish cost-benefit appraisal mechanisms. Social inequality issues we need to investigate in greater detail –those least able to buy solutions, often located in poorest condition housing stock, in most polluted areas.
- **Raise awareness** to promote political action to drive market solutions.
- **Short term gain at what health cost?** Shortage of housing can lead to inappropriate housing in urban centres. Should not continue to externalise health (psychological and physiological) repercussions.
- **Revision of building regulations** to protect against detrimental impacts on air quality – needs to operate at a pace that can keep up with the energy reduction agenda.

Tackling the impacts of air pollution outside on the breathed environment indoors

- **Lower outdoor air pollution**, tackling action at source:
  - » Polluter pays principle.
  - » Reduce (mitigate) the effects of combined heat and power (CHP) which causes increased local levels of nitrogen dioxide.
  - » Make inroads into reducing and deincentivising (non-electric) private vehicles and make all public transport electric.
  - » Investigate impacts of homes on outdoor/neighbourhood air quality –wood burning stoves, fireplaces, ventilation outlets.
  - » Investigate impacts of transport hubs on outdoor air quality in areas with housing.
  - » Consider excess heat as a pollutant – mitigating the urban heat island important for indoor air quality and needs to be considered over lifetime of buildings, accounting for anticipated changes in climate.
- **Improve urban design** to separate homes and sources e.g. avoiding homes next to busy roads and place more emphasis on assessment of the surrounding urban design's effect on ability of a home to be ventilated naturally.
- **Revisit planning considerations** currently noise, air quality externally, urban heat island, wind resistance and green infrastructure are not covered well. Are homes net contributors or net polluters of their surrounding environment?
- **Install air filtration systems**, consider carefully location of inlets.
- **Facilitate adaptive behaviour** based on levels of external concentrations.
- **Tighten enforcement and compliance of Part F but also consider whether lobbying for change is the appropriate place to focus effort on**. Might be more useful to focus efforts on developing guidance for Part F of the Planning Regulations concerning indoor ventilation, rather than change it, as with BB101 (Government guidance which describes how to meet the requirements of the regulations which apply to ventilation in schools).
- **Rapid change through prefabrication**. Could instigate change quite rapidly in off-site products e.g. pre-fabricated windows. Concern raised about trickle vents and whether they are fit for purpose.

Tackling the breathed environment indoors

- **Do not ignore the existing housing stock!** With 60–100 year + life time of homes, solutions-based R&D should include a strong focus on providing housing type and be context specific.

- **(Iterative) education of the building supply chain** (including the trades and housing providers), enforcement officers, building inspectors, landlords and residents in the causes of, impacts of and how to improve poor air quality.
- **Educate residents in domestic practices that impact on indoor air quality** e.g. drying of clothes on radiators or clothes racks indoors.
- **Develop test procedures** for cooker hood filters.
- **Alter common home design** – consider dealing of drying clothes within building design, could communal well ventilated facilities offer a healthier alternative in blocks of flats.
- **Improve post works testing, compliance and enforcement** including whether extractor fans have been installed correctly. Need to tackle rogue builders and trades whose work is resulting in poor indoor air quality and associated health effects.
- **Ventilation**: Programme in automatic start-up of extraction fans on detection of cooking.
- **Pollutant source control of materials and household product pollutant emissions labelling**, potentially make a legal requirement –other EU countries are doing it, some reached by negotiation, some by voluntary schemes backed by government. Do those specifying, designing and retrofitting homes know about the pollution properties of some materials being worked with and if they don't then help them to commission and specify in a sensitive manner. Example was shared of Allergy UK's voluntary Seal of Approval label for appliances and products in the home, a scheme now used in over 70 countries and being broadened to cover some fit out and building products.
- **Set limit levels for household products against a list of organic compounds** to assist judgement on health impacts of products. Products over the limit levels could be banned. Alternatively the limits could be used to educate the population with the emphasis being placed on the consumer rather than the manufacturer/supplier.
- **Encourage widespread installation of real-time sensors for indoor pollutants** (but need recognised standard and more assurance on calibration).
- **Develop a mechanism to monitor and investigate poor indoor air quality consistently** as has been done with noise.
- **Improve current weak warranties**.

Potential solutions we do not yet know enough about

To help make a number of the suggestions below happen, there were a few common considerations raised:

- **Consider engagement with stakeholders at each link in the supply chain**, from planners to architects, to specifiers, to buyers, to developers, to facilities managers, housing associations and householders. In doing this we must think about practicality, affordability and incentivisation in order to ensure uptake.
- **Must find a way to identify those solutions which are the most efficacious and universal** – and then put in the necessary standards and procedures with which we can measure effectiveness (types of sensors, performance verification, measurable outcomes, etc.).
- **Data sharing** – there is a considerable need to enable sharing of IAQ profiles and data and invest in longitudinal monitoring.

Tackling the impacts of air pollution outside on the breathed environment indoors

- **Ventilation**: Need to improve our understanding of the effectiveness of air filtering systems (not just of homes with nitrogen dioxide and particulates in mind, but also the outlets of commercial premises, e.g. food outlets).
- **Low carbon measures**: Need to improve our understanding of the impacts of more energy efficient buildings on indoor air quality and consequential health impacts, why does energy efficiency take primacy over health? Can we move to more win-win solutions?
- **Cost-benefit appraisa**l: These improvements of the knowledge base, combined with input from the health economics community, could help underpin indoor air quality health considerations in cost benefit assessments and options appraisals of retrofits and housing interventions.
- **Changing domestic practices, which ones improve indoor air quality; do we know**? Need to improve understanding of what householders can do e.g. sleep with the windows open (external air quality dependent).

Tackling the breathed environment indoors

- **Consumer orientated directory of solutions** required e.g. what sensors are good, how to fix simple air quality issues.
- **Wholesale directory of solutions** to meet trade needs and enable client specification for healthy materials/solutions.
- **Role of finance and risk service providers**: What's the role (and solutions that could be offered) of home insurers and providers of environmental risk analysis?
- **Need to improve understanding of what householders can do** e.g. encourage indoor plants as an air cleaning service, how cooking practices can be modified to reduce pollutant generation and exposure.
- **Could all UK products be made to be free of volatile organic chemicals (VOCs)?**

Knowledge gaps

Tackling the impacts of air pollution outside on the breathed environment indoors

- **Quality and scale of monitoring**: Need to improve quality and scale of monitoring the impact of poor quality outdoor air on the indoor environment, how outdoor pollutants interact with indoor pollutants and the role of buildings as an interface between the two.
- **Healthy transport indoors and out**: Develop transportation options that simultaneously optimise energy efficiency and cleanliness.

Tackling the breathed environment indoors

- **Inventory and hierarchy of indoor air pollutants** – needs to be established with prioritisation according to factors such as prevalence and type/extent of deleterious effects.
- **Inventory of biological, physiological and mental effects associated with each pollutant** or class of pollutant.
- **Need to understand the health impact of multi-exposures**.

- **Contextualise the effects of poor IAQ** in relation to other insults to human health in the home, e.g. nutrition, drinking water, dermal absorption, microbiological, etc.
- Improve understanding of:
  - **Fine and ultrafine particulates in the home**.
  - **Personal exposure to mould/dose relationships** –the last national study was in 1999.
  - **The causes of damp and rot/mould**. Start with the 'low-hanging fruit' when it comes to reducing/eliminating the problem. Remember that some fungicides might add to pollution loads if not fit for purpose themselves, or if misused. However, also need to understand how this problem might vary with local context e.g. homes prone to flooding vs homes in areas where weather anticipated to become hotter and drier.
  - **Designated ventilation flows**, particularly how to quantify and the use of proxies, non-linear effects (VOCs, chemistry) and the impact on health of exposure levels to chemicals released from cleaning products and fire retardants.
  - **Improve evidence base** –example given of Scottish Building Regulations now requiring CO2 sensors in bedrooms after evidence showed bedroom air quality poor.
  - **Air quality sensors**, need to know what they are measuring, how they are calibrated.
- **Feed into the next review of Part F of Building Regulations**.
- **Material science**: New materials could provide an opportunity. Should consider incentivising and stimulating production of indoor air quality enhancing materials with energy efficiency benefits. Work has been carried out already on enhancing sheep wool to absorb VOCs. Where could nano-particle surfaces and coatings help? Can materials be designed to aid moisture regulation.
- **Learn from other countries**: Apply the French and Scandinavian approaches of a rolling programme to monitor a baseline of pollutants.
- **Remember to think local**: In devising solutions and researching this area, need to reflect local circumstances and context.
- **Identify from the long list of indoor air pollutants which are the most significant in health impacts across the entire life-course**.

Summary of priorities for the working party & community action

Priorities for the working party

- Should be health-focused.
- Start with effect of indoor pollution on the health of babies and children.
- Must be a multi and inter-disciplinary group, avoid silos.
- Function must be to increase awareness of the issue as well as review the evidence base.
- Need to establish who pays for the Working Group.
- Alongside the final report, produce a targeted Plain English guide (simplicity science) articulating the levels and types of pollutants found in homes.
- Set proxies (and an agreed data format framework for easy aggregation) for measurement of indoor and outdoor air pollution.

The report should:

- Set priorities for action by all sectors and the public.
- Set priorities for pollutant control.
- Set out the associated health economics.
- Call for a multi-cross government approach with the private as well as medical, health, built environment and legal sectors.

The scope must include consideration of:

- The full consequences of residential retrofitting on energy efficiency and health and wellbeing.
- Concentration/dose-response functions.
- Prioritisation and target pollutants to focus immediate action on that will have the greatest health benefit effect.
- Where behaviour change is required and how to go about enabling it.
- Health evidence basis for building regulations and how a more integrated approach to energy efficiency and ventilation in buildings could be achieved.
- Consideration of role of urban design in contributing to increasing/lowering indoor air pollution.
- Consideration of homes as outdoor/neighbourhood pollution sources.
- Indication to developers of what 'good' looks like to increase quality and market interest.
- The role of building compliance (new build and retrofit).
- The robustness of existing data in representing the UK building stock and air quality profiles and how to improve.
- Draw from international comparisons, are there others we can learn from?

Ensure government funding for energy saving measures takes account of ventilation and indoor air quality concerns and collate knowledge, and commission research on the health impacts of energy efficiency measures.

Priorities for the community action

Collaborative working between health professionals and built environment professionals to accelerate results to action. Particularly in the following areas:

- **Radical holistic thinking required to tackle this wicked problem**.
- **A commensurate approach** if on average the proportion of the average person's time is 92% indoors, 8% outdoors, a commensurate approach should be taken to understanding and tackling pollution in the indoor environment. There's been substantial public outcry, research and parliamentary attention on the outdoor environment, we need a commensurate approach indoors.
- **Mapping** of who is involved and acting in this area.
- **How to prevent unintended consequences of well-intentioned actions**, where are the current problems, is it a lack of knowledge of how to simultaneously build energy efficient buildings that have a healthy indoor environment? Or is it a combination of knowledge and skills around design and implementation? Need to establish and address.

- **Increase numbers of indoor air quality sensors in buildings and monitoring of air quality levels**, as well as, occupant domestic practices and occupant responses to awareness of IAQ levels. This data is important for determining cause/effect of domestic practices on IAQ and will improve understanding of effectiveness of awareness raising in stimulating behaviour change.
- **Assess performance of sensors** and make available outcomes of recommendations of sensors for indoor air quality monitoring.
- **Consider opportunities that may emerge from BREXIT for improving regulation**.
- **Develop material for, and run, public awareness education campaign on "How to live, how to build, how to ventilate"**. Suggestion that the scale of the national campaign needs to be the indoor air equivalent of the litter message.
- **Make sure focus is on both new buildings and existing stock**, identify the different solutions and responses required.

Strategy for action

One of the discussion groups put forward a strategy for action that was received positively by the other delegates:

- **Support, not replicate outcomes of Each Home Counts** to deal with key indoor air quality issue of mould in homes. This requires education of the building market, amendment of Building Regulations Part F, compliance and funding.
- **Support positive changes (courage in government) to tackle outdoor air quality control at all levels** e.g. public transport and changes in energy mixes, particularly addressing concerns raised about increased uptake of biomass.
- **Focus on the gaps in indoor air quality knowledge base**. This includes:
    - » Educating the public, perhaps launching a national behaviour change campaign "How to live, how to build, how to ventilate".
    - » Implementing labelling schemes following examples from other European countries.
    - » Address knowledge gaps, building knowledge base about existing health evidence.
    - » Consider regulation of materials.
    - » Consider national schemes.
    - » Refit of non-functioning/not fit-for-purpose kitchen cooker hoods.
    - » Energy Performance Certificates within the Energy Performance of Buildings Directive take account of indoor air quality and health. During BREXIT transfer the good practice.
- **This is a neglected and overlooked field. Speed is important, not at all costs but rapid action is required**.
- **Work in a collaborative manner**. The knowledge gaps and solutions need to come from collaborative working between built environment and health professionals and other relevant sectors including financial and legal sectors too.
- **Health economics** – need to understand and evaluate these to improve communications with government about costs and benefits of solutions.

Annex 1

Mobilised community of action – personal action slips

The personal action slips provided both an insight into participants' motivation for attending, their ideas for action and what they could personally offer to take forward ideas raised at the event.

Motivations for attending

These included:

- Wishing to understand the state of current evidence for indoor air quality (IAQ) problems within homes.
- Hear more about the Working Party.
- Regulation.
- Share knowledge of emerging solutions as well as built environment activities and features causing poor IAQ.
- Help connect the Working Party with ongoing related technical activities.

A number of specific areas of interest in knowledge development were raised, particularly around improving understanding and quantifying the impact of IAQ on health, wellbeing, comfort and productivity of occupants, the impact of energy efficiency measures on IAQ, and how behaviour change can be used to improve IAQ.

Ideas for action

Metrics:

- IAQ metric development – including pollutant ranking using health metrics.

Solutions:

- Establish solutions that address IAQ without detrimentally impacting on energy efficiency including enhancing existing common construction materials to enhance indoor air quality.
- Set standards for solutions that are found to be of variable effectiveness e.g. cooker hoods.
- Consumer and trade directory of solutions.

Demonstrator:

- Healthy home demonstrator at BRE Watford.

Medical research:

- Analysis of health effects of poor IAQ across life-course.
- Relative importance of indoor pollutants and pollution sources on health, the specific health effects and how these occur.
- Establish new longitudinal study of young cohort of individuals at high risk of developing respiratory illness and monitor their exposure to pollution.
- Health economics of poor indoor air quality.

Built environment research:

- Greater data collection and evaluation in-situ of IAQ levels in homes across the British housing stock types (some indicate should be at national scale), as well as noise, temperature and relative humidity.
- Investigate poor external air quality infiltration to homes and effectiveness of purification measures.
- Assessment and verification of performance of sensors.
- Investigate actual ventilation rates for existing buildings pre and post retrofit to provide clear data for ventilation in Part F.
- Build a longitudinal dataset investigating the linkages between indoor and outdoor conditions, onto which processes and case studies can be attached and put into context.
- Develop a community facility for indoor air chemistry.

Raise awareness, educate and promote IAQ informed decision making, including:

For industry:

- Built environment supply chain, particularly those involved in retrofit which are not subject to the same level of legislation as new build.
- Relate this back to designers so that they can design for better quality internal environments.

For the public:

- Simplify the language used about indoor air quality to make the issue more understandable to non-experts.
- Household, personal care, DIY products and systems used in the home – how they can immediately improve their IAQ through better choices and behaviours and how to use to minimise detrimental impact of household activities on IAQ.
- House purchase and refurbishment – suggestion of working with estate agents to offer an optional "air quality audit" for those selling/purchasing homes.

Resources / networks sought

The majority of respondents seek collaboration opportunities, suggesting a platform that brings together medical, behavioural and built environment expertise. This should include expertise that can provide, improve and / or, innovate interim and long-term solutions, investigate under-researched areas, and assist with public messaging.

A number also sought non-financial resources in the form of publicity, access to specialist medical advice, data, and particulate matter samples as well as access to testing equipment, and occupants and buildings to study and / or monitor.

Resources / networks offered

Many offers were made of technical expertise, places to monitor, testing equipment and facilities, as well as access to networks. The summaries below highlight the surname and company of individuals +to allow for correlation with the original slips for more detail.

Technical expertise

- **Modelling and monitoring of air quality** scientific modelling to project future outdoor air quality (King, King's College London), scientific measurements of pollution within buildings and the outdoor environment (Ajibove, CETEC; Dengel, BRE; Linden, Cambridge University, Phillips, University of Chester), measurements of ventilation rates for moisture safe retrofit standard and guidelines (King, BRE) time, scientific expertise and researchers –subject to finance (Jones, University of Nottingham), condensation, relative humidity and building defects (Wright, Sustainable Homes).
- **Building indoor air quality** building performance evaluation, surveying and quantifying impact of IEQ on occupant wellbeing, health, comfort and productivity (Bruce-Konuah, Oxford Brookes University), experience of IEQ monitoring equipment, economic benefits and energy and contaminants in buildings (Pottage, Skanska; Wolley, Hilson Moran), experience of IAQ parameters in commercial environments including microbiological activity and access to extensive IAQ monitoring data as well as knowledge of current IAQ standards/limits (Stansbury, Air Quality Plan).
- **Regulations, design and product testing** 10 years' experience on scientific advisory body for building regulations (BRAC), knowledge of product data and testing (Tebbit, Robust Details), testing efficacy of IAQ improvement technologies (Dengel, BRE), researching low-carbon/natural building materials that passively improving IAQ (Maskell, University of Bath), holistic approach –linking IAAQ back to other aspects of environment and sustainable design (Paxton, Hodkinson Consultancy).
- **Behavioural change** human factors and behaviour change and ethnography and qualitative methods (Snow, University of Southampton).
- **Health** – health, epidemiology and toxicology (Holgate, University of Southampton) toxicological and historical perspectives on IAQ policy and research (Harrison, IEH Consulting), cell/molecular biology expertise and facilities, chemical analysis of particulate matter (Loxham, University of Southampton).

Places / properties to test, monitor and, or, integrate best practice

Ebbsfleet Garden City (Hughes, EDC), Sir Robert McAlpine buildings/sites in the City of London (Zakar, Sir Rober McAlpine).

Equipment / testing facilities

Integrated air quality monitoring equipment for indoor/outdoor/in-vehicle and public/commercial (Booker, NAQTS & Lancaster Environment Centre), indoor-outdoor air pollution via low speed wind tunnel (Dengel, BRE), matched-pair test house facility for systems testing and new products and strategies (Phillips, University of Chester).

Solutions

- **Guidelines** WELL FM can offer testing recommendations to improve IAQ (Tohala, Well Building Facility Management).
- **Technical** plasterboard technology (Leaning, Knauf), insight into 'connectivity' solutions (Short, Telefonica), CO2 awareness systems for offices of poor IAQ (Snow, University of Southampton).
- **Public awareness** voluntary labelling, "seal of approval" endorsement based on independent scientific testing (George, Allergy UK).

Networks

- **Industry** links to IHEEM technical working parties (Amey, IHEEM), access to clinical recruitment (Hicks, University of Southampton), links to International Energy Agency Air Infiltration & Ventilation Centre and CIBSE's Natural ventilation group (Jones, University of Nottingham), access to the MAGIC project collaborators (Linden, Cambridge University), personal network (Short, Telefonica).
- **Public/sub-sets** supporters of Allergy UK – those living with allergies (Jones, Allergy UK), sustainable and healthy homes information for B&Q customers (Tidridge, B&Q).

Promotion of material

via IHEEM channels (Amey, IHEEM), public information tools for the allergic community (Jones, Allergy UK), internally and to Kingfisher customers (Royer, Kingfisher).

Annex 2

Solution slips – solutions now and R&D required

In addition to the table discussions, individuals were encouraged to record their ideas for:

- Solutions that can be applied now.
- Potential solutions that we do not yet know enough about.
- Knowledge gaps requiring research & innovation effort.

Thirty-five solution idea slips were collected. Participants were encouraged to provide a detailed description of the idea as well as who they believe is responsible for tackling or leading on it. The ideas are summarised below with the idea slip number indicated if you wish to explore in more detail.

Solutions that can be applied now

These varied from very technical to raising public awareness to change domestic practices and product usage inside the home.

Household product labelling

- Promote use of labelling of low emitting products –already used in other European countries. **1** (policy & industry)

Encouraging innovation and testing of current market solutions

- Solutions need to be positive and desirable. **8**
- Supply chain need to be incentivised to provide products that don't give off pollutants. **29**
- New products from hybrids e.g. health-home insurance. Would require guidance, research support, particularly in high impact pollution areas. **33**
- Include and make use of the Innovate UK Catapults, particularly for testing innovative solutions. **8**
- Instigate a formal testing system for cooker hoods as actual performance is currently unknown –testing needs to cover extraction efficiency, noise and reliability. Could also modify design to integrate in sensors to monitor IAQ and to be reactive to pollutant concentrations. **11**, **12** (action by policy, industry and research)

Regulation revision, compliance and enforcement

- Urge government to ensure effective compliance with existing regulation re ventilation (Part F). **1** (action by policy)

- Update Approved Document F which covers ventilation within current building regulations (commonly known as ADF/Part F) to give better advice on air inlets to buildings to mitigate against poor external air being drawn inside e.g. on green space area rather than roadside **10**. Also, urge government to provide a more open process for long delayed update of it ADF. **1** (Part F includes performance criteria for several air pollutants including VOCs, nitrogen dioxide and carbon monoxide) (action by policy).

Health thresholds

- Develop a hierarchy of compounds prioritised according to health impact. **29**

Certification schemes

- Application of IAQ integration in building management systems for offices and schools into homes. New building certification scheme WELL (focused on commercial and institutional buildings) requires air quality monitoring to be undertaken continuously and data available to the occupants of the building. **12**

Making the public aware

- IAQ audit and grading for homes being bought/sold. Could be incorporated into the energy efficiency scoring system already used (policy, industry). **1**, **2**, **3**. In addition, industry could work with estate agents to offer an Indoor Environmental Quality audit based on data collected over the period of a week which could include IAQ and noise. This would both help consumers and could contribute to a national database. **2** (industry, research)
- IAQ household awareness system – raising ambient awareness and persuasive air quality systems e.g. combine in sensors for key pollutants per room into clocks that provide tips for how to ventilate to keep mould at bay, reduce exposure to outdoor pollutants and those generated whilst cooking. **7**, **9** (action by industry and the public)
- Clear, consistent, simple, well researched, robust advice for households on improving air quality in current homes –particularly what they can prioritise to do to improve it, reduce exposure to it from alterations through to behaviour change (e.g. outdoor planting, indoor plants, use of cooker-hoods, opening of windows, use of air fresheners) and measures that could be included in works to homes e.g. housing extensions, whole home retrofit. **4**, **16**, **29**, **32**, **34** (policy and research action required)
- Provide a directory of connected IAQ home solutions for both consumers/citizens and trade. **6** (all to act but policy most important, industry and the public and research for guidance)
- Provide consumer guide to healthy homes. **14** (action required by policy, research and industry)
- Public health messaging and awareness raising – working through patient organisations and public organisations to begin to raise awareness of IAQ, self-management tools and actions to improve IAQ. **5**, **32**, **34**
- Integrating IAQ impact on health into national curriculum – working with schools to encourage next generation awareness of health and wellbeing impact of IAQ. **5**

Working Party

- Broaden membership **8** and harness work being done e.g. Good Homes Alliance's cross sector working group on overheating currently looking at Part F and Part P and urban design issues **26**, IHEEM technical working groups **27**, as well as NHS England Healthy New Towns **8** –note NHS Healthy New Town representatives were invited to event, unable to attend but requested copy of report.
- Consult with building insurers, warranty providers and mortgage companies as to how health can be factored into quality of new building and existing homes –they have a stake in the ongoing health of the building and its impacts on the inhabitants. **15**
- Make practical, solution focused offer to Government. **8**

Plan of action

Step by step approach required for tackling outdoor air quality impacting indoor air quality. Suggestion being **19**:

- Reduce performance gap.
- Increase & target education to relevant individuals.
- Demote use of cars, especially single occupancy.
- Promote safe cycling.
- Sensitise consumers.
- Create smooth road surfaces to increase use of self-propelled wheel based transport.
- Plant trees which are proven to clean air e.g. birch trees.

Potential solutions that we do not yet know enough about

- **Ventilation**: A number of slips referred to the need to know more about solutions that involve filtration of outdoor air as it enters buildings, including whether it actually works, where it should be used and what pollutants other than small particles be 'filtered' out. **13** (action by industry and research)
- **Real-time sensors** need to develop the equivalent of smart meters to display real-time information about important indoor air pollutant. **21**, **35**
- **Existing home based financial and warranty mechanisms** –if building insurers/warranty providers/mortgage companies made aware of IAQ health impact evidence, they might be able to devise new products/update existing to reward and incentivise improved indoor air quality. **15** (action by research and industry required)
- **Consumer awareness**: ensure latest research findings on health impacts and solutions are accessible to the public –suggestion is an updateable consumer guide to healthy homes. **14** (action required by policy, research and industry)

Knowledge gaps requiring research & innovation effort

Housing stock variety: Need to know what solutions apply and would be effective for different housing types(construction types, materials, occupancy profiles) across the national housing stock, Need large scale national study to identify indoor air quality profiles, to understand sources and the pollutants, how pollutants interact as well as better understand what effect the different housing types have on outdoor air quality. **17**, **30** This requires research.

Understanding the building-outdoor environment interface: Need detailed study to understand relationships between pollution concentrations outside and pollutants indoors resulting from outdoor ingress in a variety of property types and ages and locations (for varying background concentrations). It needs to be carried out where possible pre-occupancy (before people move in, whether new build/after purchase) as well as during occupancy. This evidence would enable us to grade existing housing stock, understand impact of decoration following house purchase and inform future R&D needs to enable better air quality in homes **22**, **23**, **27**. It will require improving understanding of sensor performance, sensitivity and robustness for long-term data collection by non-experts. **23** This requires research.

Understanding the most urgent sources of indoor pollution to tackle for health: Need to better understand which are the most damaging indoor air pollutants to health and which aspects of behaviour could reduce exposure/source creation. e.g. emissions from cooking vs mould spores vs candles vs woodstoves vs outdoor pollutant ingress. Also need to understand how these emissions interact in terms of their chemistry and where they might be synergies in health effects **24**, **29**, **31**, **34**. This requires research, particularly interdisciplinary research, bringing together chemistry, clinical, biological, epidemiological and engineering expertise.

Exploring water as an indoor pollutant carrier: Need to better understand moisture effects on humans including health effects of exposure to fungi and fungicide. **29**

Understanding impact of poor indoor air quality on sleep and next day cognitive performance: High interest from industry and schools on indoor air quality in offices to improve cognitive performance. Need to investigate whether poor indoor air quality impacts on sleep resulting in next day cognitive functioning impairment. **25**

Understanding trade-offs: A number of knowledge gaps were raised including the need to resolve the trade-off between ventilation, overheating and noise levels. **10**

Windows: This knowledge can then be used to underpin advice and guidance around windows – sealing and ventilation requirements **19** and could inform development of 'smart windows' that open/close according to relative indoor/outdoor pollution (air and noise) levels.

Health economics: Health impacts of poor indoor air quality need to be converted to economic costs and the impact of healthy homes as a preventative health measure calculated to help stimulate market demand for healthy housing. **29**