Indoor Environmental Quality in Sustainable Buildings

AIVC International Workshop

Stuttgart, Germany

1-2 April 2025

Workshop description

The Air Infiltration and Ventilation Centre (AIVC) together with Fraunhofer IBP in Germany organise a workshop entitled "Indoor Environmental Quality in Sustainable Buildings" to be held on 1-2 April 2025 in Stuttgart, Germany.

The 1 ½ day workshop provides the opportunity to German researchers and engineers, as well as international experts, to present and discuss recent developments in relation to indoor environmental quality, ventilation, health and sustainability of the building stock.

This workshop is part of a series of annual international workshops, which are organized by AIVC in collaboration with national research centers or energy authorities. These workshops also target regional issues in relation to ventilation and infiltration, as part of a process of knowledge generation.

Workshop Programme

Day 1 - Tuesday, April 1, 2025			
Opening Session *Chair: Gunnar Grün, Fraunhofer Institute for Building Physics IBP, Germany*			
09:00	Indoor Environmental Quality in Sustainable Buildings at Fraunhofer IBP	Gunnar Grün, *Fraunhofer Institute for Building Physics IBP, Germany*	**Abstract**
09:20	Overview of AIVC, TightVent & venticool	Arnold Janssens, *AIVC Operating Agent/INIVE/UGent, Belgium*	**Abstract**
09:30	Introduction Heinz Trox Foundation	Christine Roßkothen, *Heinz Trox Foundation, Germany*	**Abstract**
09:40	Impact of indoor air quality on health	Ulrich Zißler, *Technische Hochschule Rosenheim, Germany*	**Abstract**
Status of implementation of EPBD-recast *Chair: Arnold Janssens, AIVC Operating Agent/INIVE/UGent, Belgium*			
10:05	Addressing Indoor Environmental Quality and inspection of ventilation systems: provisions in the EPBD Recast	Marco Morini, *European Commission, Directorate-General for Energy (DG ENER), Belgium*	**Abstract**

10:25	EPBD and Consequences for National Implementation and Relation to other EU-Legislation	Claus Händel, *Fachverband Gebäude-Klima e.V., Germany*	Abstract
10:45	***Coffee Break***		
11:15	Net Zero Energy Codes in Canada	Iain A Macdonald, *National Research Council (NRC), Canada*	Abstract
11:30	European Calculation Tools for Energy Efficient Buildings	Simon Wössner, *Fraunhofer Institute for Building Physics IBP, Germany*	Abstract
11:45	Discussion		
12:15	***Lunch***		
IAQ in relation to health *Chair: Christine Roßkothen, Heinz Trox Foundation, Germany*			
13:15	Smart IAQ Management: Enhancing Energy Efficiency in Partially Occupied Office Buildings	Lukas Schmitt, *Technische Universität Berlin, Germany*	Abstract
13:30	The harm paradigm for IAQ and IEQ	Benjamin Jones, *University of Nottingham, UK*	Abstract
13:45	IEA-EBC Annex 86: a performance based assessment method or a rating ecology?	Jelle Laverge, *Ghent University, Belgium*	Abstract
14:00	Smart ventilation performance from an international perspective	Gaëlle Guyot & Jean Paul E. Harrouz, *Cerema, France*	Abstract
14:15	Concepts of air purification efficiency tests under realistic conditions with continuous bioaerosol source and evaluation of the test results	Andreas Schmohl, *Fraunhofer Institute for Building Physics IBP, Germany*	Abstract
14:30	Discussion		
14:50	***Coffee Break***		
IEQ in sustainable buildings *Chair: Gunnar Grün, Fraunhofer Institute for Building Physics IBP, Germany*			
15:20	The TAIL rating schemes for offices and schools are the way to reduce carbon emissions and improve IEQ	Pawel Wargocki, *Technical University of Denmark, Denmark*	Abstract
15:35	Solution to Improve IEQ in Classrooms	Dirk Müller, *Heinz Trox Wissenschafts gGmbH, Germany*	Abstract
15:50	IEA EBC Annex 97 / IEA CITIES Task 5 - Sustainable Cooling in Cities	Peter Holzer, *Institute of Building Research & Innovation, Austria*	Abstract
16:05	Indoor Environmental Quality in Home Offices: A Proof-of-Concept Study on Pleasure and Discomfort	Peiman Pilehchi Ha, *RWTH Aachen University, Germany*	Abstract
16:20	Assessment of the impact of climate change on thermal comfort in buildings, taking account of occupant behaviour and the urban context	Bassam Moujalled, *Cerema, France*	Abstract
16:35	Noise characteristics and psychoacoustic of outdoor heat pumps	David Goecke, *Fraunhofer Institute for Building Physics IBP, Germany*	Abstract
16:50	Environmental impact of heating and ventilation systems in the	Yanaika Decorte, *Ghent University,*	Abstract

	LCA of a Flemish single-family dwelling	*Belgium*	
17:05	Indoor Climate in the Spotlight: Between Health Protection and Energy Efficiency	Lukas Siebler, *University of Stuttgart, Germany*	**Abstract**
17:20	Discussion		
17:50	**End of Day 1**		
Day 2 - Wednesday, April 2, 2025			
Opening Session *Chair: Gunnar Grün, Fraunhofer Institute for Building Physics IBP, Germany*			
09:00	IEQ, Ventilation and energy performance of buildings	Thomas Hartmann, *ITG Dresden, Germany*	**Abstract**
Case studies schools and care facilities *Chair: Christine Roßkothen, Heinz Trox Foundation, Germany*			
09:20	Indoor Air Quality in Naturally Ventilated Classrooms and Offices	James A. McGrath, *Maynooth University (MU), Ireland*	**Abstract**
09:35	Improving IAQ in school and Non-residential buildings: case studies	Cécile Caudron, *Cerema, France*	**Abstract**
09:50	A controlled intervention study in two schools: impact and benefits of the air cleaning measures implemented	Iain A Macdonald, *National Research Council (NRC), Canada*	**Abstract**
10:05	Improving air quality in UK schools: SAMHE – Schools' Air quality Monitoring for Health and Education	Henry Burridge, *Imperial College London, UK*	**Abstract**
10:20	Ventilation concepts in classrooms: Results of a long-term study in three elementary schools	Susanna Bordin, *Technische Hochschule Nürnberg, Germany*	**Abstract**
10:35	Discussion		
11:00	***Coffee Break***		
Demand and personal control, user interaction *Chair: Arnold Janssens, AIVC Operating Agent/INIVE/UGent, Belgium*			
11:30	NudgeFlow: The next generation of residential ventilation - tweaking the natural air flow with distributed components	Hilde Breesch, *KU Leuven, Belgium*	**Abstract**
11:45	Performance of Personalized Ventilation and Chair Fans: Experimental Measurements in a multi-occupied Living Lab	Douaa Al Assaad, *KU Leuven, Belgium*	**Abstract**
12:00	Why is PECS not a mainstream product today?	Bjarne W. Olesen, *Technical University of Denmark, Denmark*	**Abstract**
12:15	Discussion & Closing		
12:45	***Lunch***		
13:45	**End of Workshop**		

Energy in Buildings and Communities Programme

Workshop organisers

The workshop is organized by Fraunhofer IBP together with the AIVC and facilitated by INIVE (International Network for Information on Ventilation and Energy Performance).

Workshop Venue

The workshop will take place at: Fraunhofer Institute for Building Physics IBP (Nobelstr. 12, 70569 Stuttgart, Germany).

Sponsors

This workshop is financially and technically supported by The Heinz Trox Foundation.

Registration

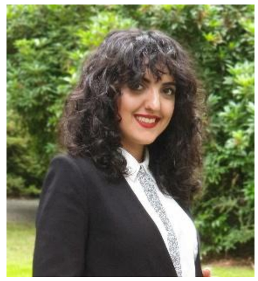
Registration is now closed.

Accommodation & Transportation

Detailed information about possibilities for accommodation and public transport is available here.

Douaa Al Assaad

KU Leuven, Belgium



Bio:

Douaa Al Assaad is a Postdoctoral Researcher at the Building Physics group of KU Leuven, Belgium. Her primary research focus lies in evaluating the performance of personal comfort systems and developing assessment frameworks, emphasizing the role of resilience as a building performance characteristic. With a Ph.D. in Mechanical Engineering from the American University of Beirut, Lebanon, she has 8 years of expertise in indoor environmental quality research. Douaa has significantly contributed to various national projects, showcasing her proficiency in diverse modeling techniques and multi-scale experimental approaches. Her belief in sustainable building solutions earned her the prestigious FWO junior postdoctoral scholarship in 2023. Currently, she delves into investigating the performance of personalized environmental control systems and their combinations, particularly their resilience under disruptions such as extreme heat events. Drawing on collaborations in international projects such as IEA EBC Annex 80, 86 & 87, Douaa brings a distinctive perspective to her research. Committed to excellence, she strives to deliver impactful contributions to the field of Building Physics throughout and beyond her Postdoctoral tenure.

Presentation Title:

Performance of Personalized Ventilation and Chair Fans: Experimental Measurements in a multi-occupied Living Lab

Abstract:

As showcased by multiple field studies, one of the main challenges continuously plaguing the building sector is the need for energy efficient means of improving occupant comfort and productivity. This had led to the emergence of personalized environmental control systems (PECS) – a type of system installed in the vicinity of each occupant and which operating conditions can be individually controlled to satisfy each occupant’s personal environmental comfort needs (acoustic, visual, thermal and IAQ). The aim of this study is to assess through experimental measurements the IAQ performance of personalized ventilation system coupled with chair fans in a mechanically ventilated multi-occupied classroom. Results showed that personalized ventilation improved the breathable air quality of all occupants by 50-66 %. PV could improve IAQ in the background by 15-20% except between occupants’ workstations where PV caused a build-up of contaminant originating from exhalation. The addition of chair fans can improve thermal comfort but can cause additional mixing deteriorating IAQ in the breathing zone by 8-15 % and in the background by 10-20%. Consequently, additional design considerations should be taken when combining PECS for comfort benefits under relaxed background conditions.

Keywords:

personalized environmental control systems, personalized ventilation, chair fans, indoor air quality

Susanna Bordin

Technische Hochschule Nürnberg, Germany

Bio:

Susanna Bordin completed her master's degree in mechanical engineering with a focus on renewable energies at RWTH Aachen University in 2014. She works as a research assistant in the field of energy efficient systems for buildings at the Institute for Energy and Building at Technische Hochschule Nürnberg. Since 2021, she has also been working on her Ph.D. at the Institute of Ecomedicine at Paracelsus Medical University Salzburg. In her studies, she integrates mechanical engineering and medical aspects to investigate ventilation concepts for classrooms and their impact on indoor climate and student well-being.

Presentation Title:

Ventilation concepts in classrooms: Results of a long-term study in three elementary schools

Abstract:

Indoor environmental quality, including temperature and indoor air quality, is essential for the comfort and health of occupants. Good indoor air quality is particularly important in frequently used spaces, such as classrooms, to reduce the spread of airborne infections. In this context an observational study was conducted to investigate the influence of ventilation concepts in real school operations on indoor environmental quality, health and energy efficiency. Three different ventilation concepts were compared: natural ventilation in combination with carbon dioxide (CO_2) traffic lights, mechanical ventilation with decentralized air handling units and a central ventilation system.

The randomized controlled trial lasted from October 2023 to April 2024 during the winter infection season. It involved the investigation of eight classrooms in three elementary schools in Germany with children in grades 2-4. One focus is on the impact of the ventilation concepts on comfort and health of the pupils. Therefore, questionnaires were used and saliva samples from pupils were collected to examine them for infection parameters. The second focus is on how the ventilation concepts affect indoor air parameters. For this purpose, a long-term monitoring over the entire study period was conducted. Various measurement data inside the eight classrooms and weather data for each school were recorded continuously.

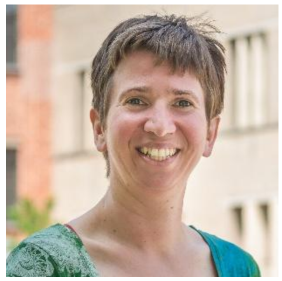
This contribution focuses on evaluating the long-term monitoring inside the classrooms to assess indoor air quality and thermal comfort, also considering natural ventilation caused by open windows. The arithmetic mean values over 45-minute school hours during occupancy are compared across the entire study period. The CO_2 concentration can be used as an indicator for the indoor air quality. The lowest CO_2 levels are observed in classrooms with decentralized ventilation units, while the highest concentrations are measured in those with a central ventilation system. Classrooms with natural ventilation maintain acceptable values below 1000 ppm most of the time. However, regarding temperature, the lowest room temperatures occur for natural ventilation. The children's perception of temperature, recorded using a comfort questionnaire, shows similar results. This study comes to mixed findings for the mechanically ventilated classrooms, underlining the importance of proper operation of ventilation systems.

Keywords:

Indoor air quality, schools, long-term monitoring, mechanical ventilation, natural ventilation

Hilde Breesch

KU Leuven, Belgium



Bio:

Prof. Hilde Breesch is an associate professor in the Building Physics and Sustainable Buildings section in the Department of Civil Engineering at KU Leuven (Belgium). She is responsible for the research line "energy performance and indoor climate". Multidisciplinary cooperation with other (inter)national research groups is important with a focus on complementarity of expertise. She has built a sector-specific network of companies through applied research projects. Hilde Breesch is also coordinator of the international dissemination platform for resilient ventilative cooling "venticool".

Presentation Title:

NudgeFlow: The next generation of residential ventilation - tweaking the natural air flow with distributed components

Abstract:

The residential ventilation market has found itself in a constant shift in its performance requirements in the last few years. During the SARS-Cov2 pandemic, the focus was on indoor air quality (IAQ) centred performance and changed during the energy crisis, to minimize the energy use. In addition, the emphasis on renovation solutions has challenged the applicability of the traditional prescriptive ventilation standards and is pushing the market towards performance-based design. Moreover, the limited space available for ventilation ducts in renovation has led to a renewed focus on natural and hybrid decentralized ventilation solutions.

Out of this context, we envision the next generation in residential ventilation system that is smart, robust, requires minimal intervention in existing dwellings and guarantees a good IAQ and low energy use. The NudgeFlow system dynamically nudges and tweaks the natural flow pattern through the different spaces in the dwelling to satisfy the instantaneous ventilation needs and flexibly adapt to the prevailing climate conditions. This novel ventilation system consists of interconnected local low pressure drop ventilation components, sensors tracking ventilation demand and climate conditions and a distributed controller adjusting the operation of these components.

The project aims to advance NudgeFlow concept by conducting research to understand airflow patterns, to establish a performance evaluation method, to find optimal design configuration(s) of the components, and to develop a control framework. A virtual test bed will be developed to demonstrate the system's feasibility and performance.

Keywords:

Residential ventilation, airflow patterns, performance, control framework, design

Henry Burridge
Imperial College London

Bio:

Dr Henry Burridge is Senior Lecturer in Environmental Fluid Mechanics at Imperial College London - with a research expertise in indoor environment & air quality. As part of his research, Henry shaped the Schools' Air quality Monitoring for Health and Education initiative, SAMHE. Through SAMHE he leads a team measuring the environment and air quality in hundreds of schools across the four UK nations; they are working to improve the air quality within UK schools, and the associated health and educational outcomes.

Presentation Title:

Improving air quality in UK schools: SAMHE – Schools' Air quality Monitoring for Health and Education

Abstract:

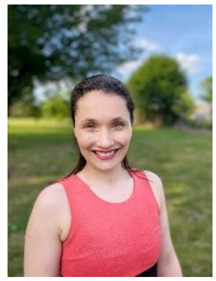
Schools' Air quality Monitoring for Health and Education – SAMHE – was started in 2022. SAMHE has used a citizen science approach to rapidly create a network of air quality monitoring in schools across the UK's four nations. More than 1,300 schools were recruited and gifted a free air quality monitor with access to the SAMHE Web App, providing pupils with visualisation of their data and interactive activities. SAMHE continues to receive data from more than 600 monitors within schools – collecting data at a rate 100,000 school data days per year – recording data every minute concerning their environment, relative ventilation rates, and indoor air quality/pollution levels. An overview of the project will be presented along with analysis of the data gathered. This has already provided revolutionary findings regarding the conditions within UK schools. These include that SAMHE classrooms typically adhere to UK guidance for classrooms (BB101, 2018) but, despite this, they exhibit low ventilation rates, 5.3 L/s/p on average, falling to 3.8 L/s/p during colder weather. With respect to pollutants, $PM_{2.5}$ is used as the core marker and the data shows that $PM_{2.5}$ in SAMHE classrooms is highly correlated (correlation coefficients of around 80%) with outdoor (reference grade) measurements made around the UK. Moreover, the data indicates an upper bound for the fraction of $PM_{2.5}$ from indoor sources as 25%, suggesting the ingress of outdoors $PM_{2.5}$ as being dominant in UK classrooms. Potential for exposure to $PM_{2.5}$ in classrooms is shown to be most significant on days with elevated outdoor concentrations; for example, days when outdoor levels exceed WHO (2021) guidance values account for 27% of potential exposure in classrooms, whilst only accounting for 6% of the total school days.

Keywords:

Air quality, ventilation, particulate matter $PM_{2.5}$, schools

Cécile Caudron

Cerema, France



Bio:

Cécile Caudron works in Cerema – France. She is deputy head of the sustainable building group in Lille (Hauts-de-France region), and more specifically oversees the Performance of Buildings theme. She is co-managing the activity regarding Indoor Environment Quality and Ventilation in the Cerema (20 persons throughout France).

She has been working in the building sector for 12 years, focusing on Indoor Air Quality for over 9 years. Before that she has been head of a unit dedicated to building thermics, mandatory building inspection, property management and hygrothermal transfers, for 3 years at Cerema's Autun branch (Burgundy region). She was working on hygrothermal transfers in building walls.

Cécile Caudron is graduated from ENTPE (engineer school) and since 2020 a ministry-recognized expert in the building sector.

Presentation Title:

Improving IAQ in school and Non-residential buildings: case studies

Abstract:

When energy savings are often opposed to the need to renew classroom air, Cerema and Ifpeb wanted to demonstrate by example that a balance was possible. The Hub Air Energie project brought together a community of public and private stake-holders willing to combine good indoor air quality (IAQ) with controlled energy consumption. For a period of 24 months, 10 schools and 5 commercial buildings have been supported and monitored. Each partner's individual learning experience was structured around 4 pillars: Understand, Analyze, Act and Exchange. Workshops were organized in each site to raise awareness among the occupants.

Here are some of the key messages coming out from this experiment:

- Characterizing the objectives of a good IAQ, easily measurable over time, around 3 compounds (carbon dioxide – CO_2, total volatile organic compounds – tVOC, and fine particles – $PM_{2.5}$), gives an initial indication of the overall state of IAQ at the site, easily understandable by stake-holders.
- IAQ was quite good on the panel of 15 Hub Air Energie buildings, but buildings with mechanical ventilation achieved better overall IAQ than buildings without ventilation system. Buildings

using only airing through windows for air-renewal, but implementing a reinforced airing protocol, achieved IAQ levels, in some rooms, close to those of sites with defective mechanical ventilation systems (design, implementation, maintenance).
- A mechanical ventilation system has a significant effect on the reductions of CO_2 and $PM_{2.5}$ concentrations, but its impact on tVOCs concentration was not as significative on the panel studied (occupants have a key impact on these peaks, identifying sources of pollution remains essential).
- Energy efficiency must be a lever for progress in IAQ. It is economically more accessible to integrate IAQ criteria alongside energy criteria right from the design stage. In operations, the team found it easier to integrate IAQ reflexes alongside energy reflexes, rather than making them a separate subject. The same contact person should be able to handle both subjects in synergy.
- Setting up a commissioning for a new ventilation system, or re-commissioning of existing one, helps to ensure that fresh air is delivered to the right place at the right time.

This program has been funded by Ademe and the French Ministry for Ecological Transition.

To complete this approach and to go further in the dissemination, this project continues with a dissemination task in the CleanAirBouw project, funded by Interreg France-Wallonie-Vlaanderen (project management: Université Littoral-Côte-d'Opale; dissemination management: Cerema). This task of the CleanAirBouw project focuses on 3 target audiences: schools (the target of interest in this topic), students and professionals. For schools, an IAQ challenge will be organized between September 2026 and June 2027, among 20 schools in the Hauts-de-France region and Belgium, with 2 classes per school. The objectives for the 40 participating classes are to achieve:

- the best possible IAQ over the duration of the challenge,
- the best progress,
- and the best communication with non-participating classes in their school.

Workshops will be held throughout the year to raise awareness on IAQ issues and on improving it in the classroom. If this new experimentation is successful, it should induce a wider offer to local authorities in the 2 countries.

Keywords:

IAQ, air renewal, energy consumption, school, dissemination

Yanaika Decorte

Ghent University, Belgium

Bio:

Yanaika Decorte is a postdoctoral researcher at Ghent University. She graduated as a Master of Science in Engineering: Architecture—Architectural Design and Construction Techniques—at the same university in 2019. After her graduation, she joined the Building Physics research group, where she collaborated for one and a half years on two research projects: the European Interreg project INDU-ZERO and the TETRA project LCC Ecotoop. She received an FWO grant in 2021 to start her PhD research. Recently, she obtained het PhD titled 'Three Pathways towards a Sustainable Transition of Flemish Dwellings: What Are the Shifts in the Environmental Trade-Off?' (promoters Prof. Marijke Steeman and Prof. Nathan Van Den Bossche). Her research investigated the environmental impact of deep energy renovation, reconstruction, and step-by-step renovation to improve the energy performance of Flemish single-family dwellings. Additionally, she developed an LCA framework that allows for a fair comparison of these pathways. As a postdoctoral researcher, Yanaika continues her research on the environmental impact of energy renovations. She is currently involved in a project in collaboration with the City of Ghent investigating renovation strategies that incorporate sustainable HVAC installations for existing terraced dwellings in an urban context.

Presentation Title:

Environmental impact of heating and ventilation systems in the LCA of a Flemish single-family dwelling

Abstract:

In recent decades, efforts to reduce the operational energy use of buildings have led to the adoption of thermal insulation and more efficient heating and ventilation systems. However, this has increased the relative importance of embodied impacts, which stem from the production, transportation, installation, and disposal of building materials and technical installations. Life cycle assessment (LCA) is widely used to evaluate the environmental impact of buildings, but the embodied impact of heating and ventilation systems is often omitted or considered in a highly simplified manner, typically accounting only for primary components such as the generation system. Today, limited knowledge exists regarding which individual components of heating and ventilation systems are critical to include in LCA studies and how they contribute to the building's embodied and life cycle impact.

This study investigates (1) the significance of individual components in heating and ventilation system design, (2) the relative contribution of technical installations to embodied and life cycle impacts at the building level, and (3) the difference between a detailed approach (considering the generation system, emission system, distribution system, and other associated components) and a simplified approach (including solely generation systems). This research assesses the environmental impact of three heating systems and two ventilation systems in a Flemish single-family dwelling over a 60-year study period, following a cradle-to-grave approach. The heating systems analysed include a condensing gas boiler, a brine-water heat pump, and an air-water heat pump combined with underfloor heating. The ventilation systems considered are a demand-controlled exhaust ventilation system and a balanced ventilation system with heat recovery.

The findings indicate that a simplified approach, which accounts only for generation systems, underestimates the building's embodied and life cycle impact by 8–12% and 4–6%, respectively. Heating and ventilation systems contribute between 12–33% of the total embodied impact and 5–20% of the overall life cycle impact. The significance of individual components highly depends on the heating and ventilation concept. The study highlights that limited data on technical installations' embodied impacts hinders accurate LCAs. Expanding data availability would facilitate more frequent inclusion of technical installations in LCA studies and improve accuracy. Moreover, assessing the embodied impact of technical installations requires a large data inventory, making further detailed LCA studies essential for the development of simplified approaches that do not compromise the robustness of the results.

Keywords:

Life cycle assessment, Embodied impact, Heating systems, Ventilation systems, Single-family dwelling

David Goecke

Fraunhofer Institute for Building Physics (IBP), Stuttgart, Germany

Bio:

David Goecke is a highly qualified professional currently serving as the Group Manager for Noise Control and Vehicle Acoustics at the Fraunhofer Institute for Building Physics (IBP) in Stuttgart, a position he has held since 2024. He was born on March 25, 1988, in Berlin and has a strong academic background in acoustics. Goecke earned a Master of Science in Media and Audiotechnology from TU Ilmenau in 2014, followed by a Master of Acoustics from the University of Stuttgart in 2019. Before his current role at the IBP, he worked as an acoustics engineer for vehicle acoustics at M-Plan GmbH from 2015 to 2020. He became a certified data scientist specialized in data analytics in 2021, enhancing his expertise in sound analysis and data-driven approaches. Goecke has been a research associate in building acoustics at IBP from 2020 to 2024, where he focused on sound immission control and psychoacoustics.

David Goecke is an active member of the German Society for Acoustics (DEGA) since 2020 and has been part of the DEGA Technical Committee for Vehicle Acoustics since 2024. His specialized interests include building acoustics, vehicle acoustics, sound analysis, and artificial intelligence in data analysis.

Presentation Title:

Noise characteristics and psychoacoustic of outdoor heat pumps

Abstract:

Heat pumps are vital for achieving climate-neutral indoor heating and air conditioning, with air-source heat pumps comprising over 70% of the market. However, their increasing prevalence raises concerns about noise emissions, necessitating focused efforts to mitigate these impacts. The network of the publicly funded QUEEN-HP MENESA project addresses this challenge through comprehensive investigations and acoustic evaluations aimed at reducing noise and vibration from outdoor heat pump systems.

To facilitate this research, two specialized laboratories have been established at Fraunhofer IBP. The first, a hemi-anechoic chamber, is equipped with temperature control to enable standardized measurements at -7 °C and 7 °C. This facility employs a movable microphone arrangement to capture spherical sound radiation patterns, allowing for detailed assessments of source location, radiation contributions, and sound power across various operational conditions of the heat pump. The second

laboratory, designed as a reverberation chamber, incorporates a reception plate for measuring impact sound, forces, impedances, and sound power. These measurements provide essential input data for simulations predicting vibration distribution within buildings and sound radiation into indoor spaces.

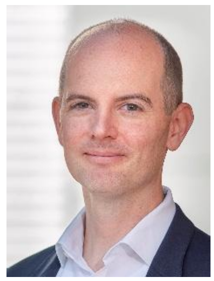
In parallel, the project recognizes the importance of psychoacoustics, which studies human sound perception. Standardized assessment procedures outlined in DIN ISO 12913 emphasize psychoacoustic mapping, introduced in 2021, to better represent perceived noise pollution. Traditional sound pressure levels often fail to capture the true impact of noise, highlighting the need for a psychoacoustic perspective that incorporates metrics such as loudness, sharpness, and tonality. A second project, which will be presented in context, aims to integrate acoustic measurements from the heat pump evaluations with psychoacoustic analyses to create software for psychoacoustic mapping. This approach enables more accurate assessments of environmental noise and enhances the understanding of how heat pump noise affects human perception. An illustrative case study demonstrates the calculation of psychoacoustic mapping using heat pump measurements as sound sources.

Keywords:

Heat pump noise, radiation, vibration, psychoacoustics, noise pollution, soundscapes

Gunnar Grün

Fraunhofer Institute for Building Physics IBP, Germany



Bio:

Prof. Dr.-Ing. Gunnar Grün has been a professor of building physics at the University of Stuttgart, Institute for Acoustics and Building Physics (IABP) since 2019. In addition to his academic role, he serves as the deputy director of the Fraunhofer Institute for Building Physics (IBP) since 2016. Prior to this, he was the head of the Department of Energy Efficiency and Indoor Climate at Fraunhofer IBP from 2015 to 2021 and a professor for System Integration of Efficient Buildings at Technische Hochschule Nürnberg Georg Simon Ohm from 2015 to 2019.

Dr. Grün has a robust background in indoor climate research, having led the Department of Indoor Climate at Fraunhofer IBP from 2011 to 2015 and managed indoor climate systems from 2009 to 2011. He has been a dedicated scientist at Fraunhofer IBP since 2005. Dr. Grün earned his doctorate in civil engineering from the University of Stuttgart in collaboration with Fraunhofer IBP between 2005 and 2008, following his civil engineering studies at the University of Stuttgart (1999-2005) and the University of Calgary, Canada (2003-2004).

Presentation Title:

Indoor Environmental Quality in Sustainable Buildings at Fraunhofer IBP

Abstract:

For good indoor environmental quality in sustainable buildings, we need innovative solutions that reduce energy consumption and the associated ecological footprint while promoting a healthy indoor climate.

In the field of ventilation, the Fraunhofer Institute for Building Physics (IBP) deals with various aspects of indoor air quality, energy efficiency and thermal comfort in buildings. This includes, among other things: Development and optimization of ventilation systems and components, air flow and air distribution, the investigation of air filter technologies, the analysis of thermal and acoustic comfort and the health effects of indoor air quality.

Air cleaning technologies are being developed to improve indoor air quality - as the coronavirus pandemic has shown in particular. To this end, we have developed procedures to evaluate the efficiency

of devices in removing particles, allergens and pollutants from the air. At the same time, we are looking at noise generation and measuring the noise level under different operating conditions, as well as monitoring energy consumption of devices during operation.

When assessing the energy efficiency of buildings, ventilation is considered by aspects such as system efficiency, ventilation heat losses, air exchange rates, usage profiles, etc. To this end, we develop calculation algorithms such as the ‘ibp18599kernel’, which implements the assessment of the European requirements from the European Performance of Buildings Directive in Germany. In addition, we develop methods for life cycle analysis in order to record the environmental impact over the entire life cycle of ventilation systems and to integrate the required data basis, e.g. from environmental product declarations.

Keywords:

Indoor Environmental Quality, Sustainability, Indoor Air Quality, Air Cleaning, Energy Efficiency Assessment

Gaëlle Guyot

Cerema, France

Bio:

Dr Gaëlle Guyot is the deputy head of the research team Performance of buildings in their environment at Cerema, the French public agency for developing public expertise in the field of ecological and energy transition.

She graduated with three master's degrees in 2006-2007 and she received later on her PhD from the Savoie-Mont Blanc University in 2018. Since 2006 at the Cerema, she has been interested in the complexity of the interactions between the different air flows in buildings and their impact on energy, comfort, indoor air quality, the propagation of an accidental toxic cloud, the transmission of viruses and, above all on health.

Cerema is a place where research actions make it possible to remove obstacles in order to anticipate and support the evolution of regulations in France and in Europe, for buildings that meet the challenges of climate and public health. The improvement of the quality of ventilation and airtightness of buildings, the development of methods to assess the performance of ventilation at the design stage, the sustainability of performance, the development and promotion of promising strategies such as smart ventilation, are her favourite crucial research topics.

She is the co-author of about 60 articles in international journals and conferences and represents France on the AIVC board. She co-supervises several Post-Doc and PhD thesis and have participated in many collaborative projects in France and in Europe. She has been an invited Professor during several weeks/months at LBNL Berkeley lab (USA), Pontifical Catholic University of Paraná (Brasil), and Victoria University of Wellington (New-Zealand).

Presentation Title:

Smart ventilation performance from an international perspective

Abstract:

Smart-ventilation with airflows adapting to the need of buildings reduces energy consumptions and can improve IAQ. In some countries, smart ventilation strategies have been widely used for a long term (like Belgium, France,…). We still need to quantify IAQ and energy benefits of smart ventilation through a common internationally validated performance assessment scheme developed in the framework of the

IEA-EBC Annex 86. The SmartAIR French project focuses on the adaptation of the tools developed in the framework of the Annex 86 project and test their relevance in the context of the generalization of humidify-based ventilation and the innovation towards new ventilation systems.

Since 2018, new research has been published and collected, notably in the context of the IEA-EBC Annex 86 - Energy Efficient Indoor Air Quality Management in Residential Buildings (2022-2025) with a series of deliverables to be published shortly. In this Annex, the preliminary scheme developed by (Poirier et al., 2021b) based on 5 indicators based on relative humidity, CO_2, formaldehyde and PM2.5 with associated input data on emission scenarios (Poirier et al., 2021a) has been extended and tested in a common exercise performed in 5 countries (France, Denmark, Belgium, Brazil, Austria).

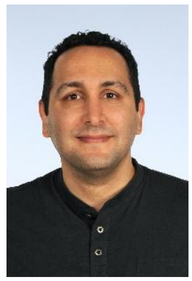
This paper will illustrate IAQ and energy performance of a set of 8 smart ventilation strategies based on the modelling of two typical dwellings selected in the French context, with boundaries conditions varying throughout Europe. Most cases selected the same input values, such as CO_2 and humidity emissions, while the occupancy schedules, cooking and showering times and duration varied to better represent the country's habits.

Keywords:

Smart ventilation, energy, buildings, indoor air quality, modelling

Peiman Pilehchi Ha

RWTH Aachen University, Germany



Bio:

Peiman Pilehchi Ha is a researcher and educator specialising in sustainable building design, daylighting, and data-driven approaches to enhancing health and wellbeing in the built environment. As a postdoctoral researcher at Uniklinik RWTH Aachen, his work integrates building performance simulation, circadian lighting, and occupant-centric design strategies to create resilient and adaptive spaces that empower human health and wellbeing. His research has been published in high-impact journals, and he actively contributes to advancing knowledge at the intersection of architecture, environmental quality, and occupant-centered design.

Presentation Title:

Indoor Environmental Quality in Home Offices: A Proof-of-Concept Study on Pleasure and Discomfort

Abstract:

Remote work has become increasingly common. Hence, it is critical to understand better the prevailing indoor environmental quality, including the domains of thermal, visual, acoustic, and air quality, and their influence on well-being in work-from-home environments. Further, limited research has explored how these factors interact with subjective perceptions of pleasure and discomfort and physiological stress indicators like heart rate variability and blood pressure.

This study employed a mixed-methods approach, combining objective environmental measurements with subjective diary entries and physiological monitoring. Fourteen participants, working from home, were asked to document their pleasure or discomfort through diary entries over 3.5 days each. Environmental sensors were used to continuously record data on temperature, humidity, CO_2 levels, sound pressure level, and light. Simultaneously, physiological metrics such as heart rate and blood pressure were tracked. Mixed-effects models were employed to analyse the relationship between environmental conditions and both subjective and physiological responses, accounting for individual variability.

The findings reveal that lower temperatures and high humidity were strongly associated with discomfort, while higher CO_2 levels and noise were linked to increased physiological stress, as reflected

by lower heart rate variability and higher blood pressure. Specifically, participants reported thermal discomfort most frequently, with temperature and humidity significantly correlated with both subjective comfort and heart rate variability. Reports of visual and acoustic discomfort were less frequent but still noteworthy, especially under conditions of poor lighting and high sound levels. In contrast, moments of pleasure were reported very few times, primarily linked to favourable environmental conditions, such as sunlight, fresh air, or enjoyable acoustic experiences, underscoring the potential for optimised indoor environments to enhance well-being. Notably, multi-domain discomfort was correlated with higher stress levels. These findings align with the concept of sensory boredom, which suggests that contemporary built environments hardly offer relevant stimuli for human sensory system.

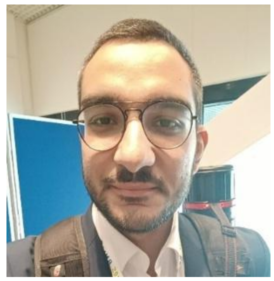
The results highlight the complex interplay between indoor environmental quality factors and stress responses in home offices. Poor indoor environmental quality, especially concerning temperature and CO_2 levels, significantly influences both comfort and physiological markers of stress. These findings suggest that optimising environmental conditions in working from home setups is crucial for enhancing comfort and reducing stress, which, in turn, can promote well-being. Future research should explore more longitudinal data to assess long-term health outcomes associated with chronic exposure to poor home office environments

Keywords:

Remote work stress, well-being, occupational health, multi-domain comfort

Jean Paul E. Harrouz

Cerema, France



Bio:

Jean Paul E. Harrouz has a PhD in Mechanical Engineering from the American University of Beirut, Lebanon. He received his B.E in Mechanical Engineering from the Lebanese University where he worked on the optimization of heat distribution in tunnel ovens using computational fluid dynamics. During his thesis, he worked on the design and integration of evaporative cooling devices with other passive systems for sustainable cooling through simplified mathematical modeling. His main focus work involves the investigation of the performance of novel sorbent material for carbon and humidity capture from confined spaces in novel thermally-driven sustainable ventilation strategies to reduce the need for outdoor air to ultra-low levels. Currently, he is a postdoctoral researcher in the BPE research team at Cerema, France where he is working on the development of a new climatic chamber to test the ventilation effectiveness of air distribution terminals with respect to pollutants transfer

Presentation Title:

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Abstract:

Smart-ventilation with airflows adapting to the need of buildings reduces energy consumptions and can improve IAQ. In some countries, smart ventilation strategies have been widely used for a long term (like Belgium, France,…). We still need to quantify IAQ and energy benefits of smart ventilation through a common internationally validated performance assessment scheme developed in the framework of the IEA-EBC Annex 86. The SmartAIR French project focuses on the adaptation of the tools developed in the framework of the Annex 86 project and test their relevance in the context of the generalization of humidify-based ventilation and the innovation towards new ventilation systems.

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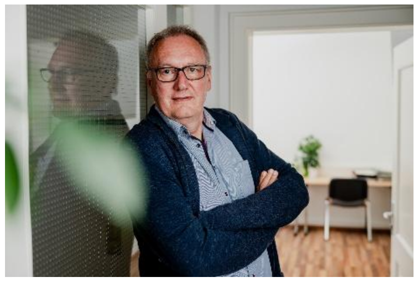
Keywords:

Smart ventilation, energy, buildings, indoor air quality, modelling

Claus Händel

Fachverband Gebäude-Klima e.V., Germany



Bio:

Claus Händel has been working in the field of air conditioning and building services engineering for over 35 years. Since 2000, he has been working as a technical consultant at the Fachverband Gebäude-Klima e.V., where he is responsible for technical and standardisation issues in the field of air conditioning and ventilation technology. He plays a key role in many DIN and CEN standardisation committees in the field of ventilation and air-conditioning technology and is chairman of several committees.
Since 2010, he has also worked as Technical Secretary at the European Ventilation Industry Association (EVIA). There, he coordinates the working groups on domestic ventilation, ventilation technology and fans for the areas of ecodesign and building energy.
Managing Director Technology at the FGK since 2022.

Presentation Title:

EPBD and Consequences for National Implementation and Relation to other EU-Legislation

Abstract:

The publication of DIRECTIVE (EU) 2024/1275 on the energy performance of buildings (EPBD) 24th April is an important step to implement important and challenging requirements in national building regulations. The presentation will give an overview with the key topics IEQ and life-cycle GWP for buildings and related standards and other regulation. EPBD is a directive which specifies minimum requirements and gives member states and even regions space for interpretation for their implementation. A common set of CEN standards is available and this needs to be revised for new EPBD requirements. Member states might use this common set or use and develop their own tools and standards for national implementation. A risk for market fragmentation and national product declaration especially for technical building systems. Product declarations shall fulfil the EPBD requirements and also product specific requirements which might not be linked to buildings and shall not lead to multiple regulation for identical products.

There are two main regulations specifying minimum requirements for products for buildings und common market aspects:

- REGULATION (EU) 2024/3110 27 November 2024 laying down harmonised rules for the marketing of construction products and repealing Regulation (EU) No 305/2011 (CPR) and
- REGULATION (EU) 2024/1781 of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products and repealing Directive 2009/125/EC (ESPR and former ErP)

As a general rule EPBD is linked to CPR with exemptions to products already regulated by ErP(ESPR). This is the case for heating, cooling and ventilation systems.
The challenge is to develop CEN standard for buildings, technical building systems and products which are acceptable for member states (more driven by a building view and national specialities) and for manufacturers (more driven by common market principles).
The presentation will identify the key aspects and possible levels of play and needs for clarification. The EU-commission is also preparing a set of guidance documents for a common interpretation. National government representatives and authorities as well as experts and industry shall acknowledge, that multiple regulation will lead to higher cost with low gain.

Keywords:
Energy performance of Buildings EPBD, Ecodesign ESPR, Construction Product CPR, indoor air quality, product declaration, life-cycle analysis, Environmental Product Declaration.

Thomas Hartmann

ITG Dresden, Germany

Bio:

Prof. Dr.-Ing. Thomas Hartmann (born 1967) has been Managing Director of the ITG Institute for Building Systems Engineering Dresden Research and Application since 2004. His work focuses on research projects and studies on the topics of ventilation, indoor air quality, thermal comfort and air conditioning. In this area, he is active in various German and European standardization committees in the field of energy efficiency of buildings and design of building systems. Since 2006, he has been teaching air conditioning and refrigeration technology at the University of Applied Sciences in Leipzig and is also active in the training of energy consultants.

Presentation Title:

IEQ, Ventilation and energy performance of buildings

Abstract:

The revision of EN 16798-1 is based on the splitting of the standard into 5 parts: 1) 1.1: Principles, 2) 1.2: Thermal Comfort, 3) 1.3: Indoor Air Quality, 4) 1.4: Lighting, 5) 1.5: Acoustics

Part 1.2 specifies the relevant parameters for determining the indoor thermal comfort in buildings and how these parameters are used for building system design and assessment of energy performance. This document gives input parameters for the design and assessment of the building envelope, heating, cooling, air systems and its control and automation systems. In addition to the parameters, the methods for steady-state and transient cases are considered.

Part 1.3 specifies the relevant parameters for determining the indoor air quality in buildings and how these parameters are used for building systems, design, assessment, operation, and energy performance calculations. This document includes design criteria for the ventilation of buildings in both residential and non-residential buildings. This document gives the relevant input parameters for the design and assessment of the ventilation, air treatment systems, building automation and control systems. In addition, it proposes different methods (maybe additional performance-based method and airborne transmission method) for determining the indoor air quality and classes for different limit

values. An important point of revision is dealing with method alignment. In addition to air change rates, the possibilities of air cleaning are increasingly being considered.

In the revision, transient aspects and performance-based designs will be given greater weight. At the interface with the EPBD, the definition of key performance indicators (KPIs) like for example a yearly thermal comfort score (TCS) is important and will be an essential part of EN 16798. Further coordination between EN 16798-1 and ISO 17772-1 is still open.

Keywords:

Thermal comfort, Indoor air quality, Ventilation design, Ventilation assessment, Key performance indicator

Peter Holzer
Institute of Building Research & Innovation, Austria

Bio:

Peter Holzer, graduate mechanical engineer, PhD in Architecture, is a researcher, consultant and teacher. He specializes in sustainable and healthy built environments, climate-responsive design, and low carbon heating, ventilation and cooling.

Following a 16 year academic career, he is Managing Director of an engineering consultancy office, Larix Engineering, and shareholder of a private based research institute, IBR&I Institute of Building Research & Innovation, both in Vienna.

Peter Holzer is consultant for both the municipality of Vienna and the Austrian Ministry of Climate Action in topics of energy transition towards zero carbon economy.

From 2014 to 2018 he joined IEA EBC Annex 62 Ventilative Cooling.

From 2019 to 2024 was Operating Agent of IEA EBC Annex 80 Resilient Cooling.

Presentation Title:

IEA EBC Annex 97 / IEA CITIES Task 5 - Sustainable Cooling in Cities

Abstract:

In Nov 24, the Executive Committee of the International Energy Agency´s Technology Collaboration Programme of Energy in Buildings and Communities has started the preparation of a new research programme, Annex 97, on Sustainable Cooling in Cities. Furthermore, the programme will be conducted as Task 5 of the IEA Technology Collaboration Programme of Cities.

This programme is a thematic continuation to Annex 80, Resilient Cooling of Buildings, which have been conducted from 2019 until 2024. Already in Annex 80, there has been a fruitful cooperation with AIVC and INIVE. The new Annex 97, again, will touch many aspects of Air Infiltration and Ventilative Cooling. It is open to attendants from research as well as industry as well as governmental and interest bodies.

With this contribution to the AIVC-Fraunhofer IBP Workshop 2025 in Stuttgart we offer to present the core objectives and organisational framework of the new Annex and invite for cooperation.

Background: Climate Change hits the world, raising challenges to the built environment, in terms of quality of life, health and safety, energy consumption and CO_2 emissions. Cities are particularly affected. Annex 80 Resilient Cooling of Buildings, told us, that energy efficient and resilient cooling of buildings is

bi-directionally connected to heat mitigation in cities. Therefore, the new Annex 97 will, amongst others, focus on the interaction between outside and inside environmental qualities, leading directly to questions in the field of Air Infiltration and Ventilative Cooling.

Objectives: The general objective of Annex 97 is to increase and spread knowledge about connected urban heat mitigation and sustainable cooling strategies. Emphasis will be placed on the interaction between heat mitigation in outdoor spaces and cooling of buildings. The aim of the project is to develop and support the application of measures that serve the health, safety, and wellbeing of people and that push energy efficiency and open the way to carbon neutrality.

Research Programme: The research programme is structured in sub-tasks:

Subtask A – Fundamentals: Develop a sound knowledge base of comfort targets, health needs and performance indicators, meant to improve effectiveness and precision in performance-assessments and developments of heat mitigation strategies and sustainable cooling applications.

Subtask B – Methods: Develop a set of connected methods for development and evaluation of cooling solutions and heat mitigation strategies, both experimental and numerical, meant to enable accurate planning and evaluation of measures of heat mitigation strategies and sustainable cooling applications.

Subtask C – Solutions: Review, compare, develop, and improve sustainable cooling solutions, together with heat mitigation strategies, meant to bring them into application and, thus, support energy and carbon efficiency of cooling as well as comfort and liveability in and around buildings.

Subtask D – Policy: Review and compare existing policies and standards. Strengthen networks and support implementation of policies, meant to spread best practice examples, and encourage their multiplication.

Conclusions and Offers: IEA EBC Annex 97 will establish a platform of international research and collaboration on Sustainable Cooling in Cities, including aspects of Air Infiltration and Ventilative Cooling. The programme invites colleagues from research as well as industry as well as governmental and interest bodies to participate. Terms of participation will be presented at the workshop.

Keywords:

Urban heat mitigation, sustainable cooling of buildings, indoor and outdoor environmental qualities

Arnold Janssens

AIVC Operating Agent/INIVE/UGent, Belgium

Bio:

Arnold Janssens (°1967) is senior full professor of building physics and building construction applications at the Faculty of Engineering and Architecture at Ghent University in Belgium. After obtaining a doctorate in applied sciences at the Laboratory of Building Physics at KU Leuven in 1998, he started as assistant professor at the Department of Architecture and Urban planning of Ghent University in 1999, and was appointed full professor in 2012. In between 2014 and 2020, he was also head of the Department of Architecture and Urban Planning. From 2020 until 2022 he was appointed special commissioner for the university wide policy choice 'sustainability' at Ghent University.

He has been teaching courses on 'building physics', 'building acoustics and lighting', 'residential comfort systems', 'building performance simulation' and 'building physics: advanced topics' within the architectural and civil engineering programmes.

He is in charge of the research group Building Physics at Ghent University, which consists today of 4 professors, 7 postdocs and 20 pre-doc researchers. He and his co-workers wrote over 350 research articles published in international journals, proceedings of international conferences and books.

He has been involved in several research projects within the EBC-programme of the International Energy Agency (Energy in Buildings and Communities). One of those is the Air Infiltration and Ventilation Centre AIVC, for which he has been board member representing Belgium since 2012, and for which he acts as co-operating agent since 2022 together with dr. Peter Wouters. He is member of the editorial board of the International Journal of Building Physics (since 2016), and the International Journal of Ventilation (since 2017).

Presentation Title:

Overview of AIVC, TightVent & Venticool

Abstract:

This talk presents the Air Infiltration and Ventilation Centre AIVC, the Building and ductwork airtightness platform TightVent, and the platform for resilient ventilative cooling venticool. These organisations are knowledge and dissemination platforms which collect information and create knowledge by collaboration with international partners, and have a long history.

The AIVC (Air infiltration and Ventilation Centre) is the International Energy Agency's information centre on energy efficient ventilation, which was created in 1979. The AIVC's main goal is to provide reference information on ventilation and air infiltration in the built environment with respect to efficient energy use and good Indoor Environmental Quality (IEQ), in collaboration with other international organisations such as TightVent and venticool. Since 2011, AIVC activities have been structured around thematic projects, resulting in different dissemination outputs, for example webinars, conference sessions, information papers, and technical reports. Recent projects include the development of papers giving an update on the current regulations in various countries regarding building and ductwork airtightness, and regarding ventilation. For the ventilation status, specific attention is paid to in situ ventilation system performances, ventilation system inspection, and the influence of the Covid19 crisis. Very relevant is the substantial interest in ventilation in the EPBD revision and the mandatory part about inspection.

Keywords:

AIVC, TightVent, Venticool

INIVE

Fraunhofer IBP

EBC Energy in Buildings and Communities Programme

Benjamin Jones
University of Nottingham, UK

Bio:

Benjamin Jones is an Associate Professor at the University of Nottingham. His research focuses on measurement and modelling approaches to indoor environments that inform policies for low-carbon, healthy buildings. He examines energy-efficient ventilation and its impact on indoor air quality and occupant health. He represents the UK on the board of the Air Infiltration and Ventilation Centre (AIVC) and serves on ASHRAE's Environmental Health Committee. He has advised the UK and Chilean governments on pandemic responses and contributed to ASHRAE Standard 241, the first global standard for controlling infectious aerosols in buildings.

Presentation Title:

The harm paradigm for IAQ and IEQ

Abstract:

Exposure limit values (ELVs) are widely used to regulate indoor air quality (IAQ), but authorities set different values for the same contaminants. ELVs establish concentration thresholds without directly accounting for health impacts across a population, leading to inconsistent protection from chronic harm. A harm-based approach offers a more effective alternative. Disability-Adjusted Life Years (DALYs) quantify disease burden, where one DALY equals one year of healthy life lost. The new Harm Intensity metric links contaminant concentration to years of life lost from premature mortality and morbidity. By multiplying a contaminant's concentrations by its Harm Intensity, total population harm is estimated, allowing direct comparison of health impacts across contaminants. Contaminants are then be ranked by the harm they cause, the most harmful are targeted for removal and regulated, and all others are ignored. This method prioritizes contaminants based on actual health risks rather than arbitrary limits, supporting more effective IAQ management and regulation.

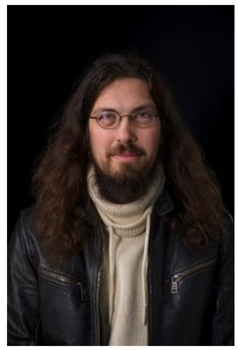
The DALY and Harm Intensity metrics could also be used to consider the health impacts of factors that affect indoor environment quality (IEQ), such as lighting, thermal comfort, and acoustics.

Keywords:

DALY, exposure, population, regulation, standard, harm budget, ELV

Jelle Laverge

Ghent University, Belgium



Bio:

Jelle Laverge is the chair of the department of Architecture and Urban Planning at Ghent University, Belgium. Their research focuses on the performance assessment of indoor air quality management strategies, HVAC and DHW systems. They serve as the secretary of the International Society of Indoor Air Quality and Climate (ISIAQ) and were the president of its flagship 'Indoor Air' conference in 2016. They are active in various working groups within CEN TC 156: Ventilation for Buildings and are the operating agent of IEA-EBC Annex 86 Energy Efficient Indoor Air Quality Management in Residential Buildings.

Presentation Title:

IEA-EBC Annex 86: a performance based assessment method or a rating ecology?

Abstract:

IEA-EBC Annex 86 'Energy Efficient IAQ Management in residential buildings' proposes an integrated rating method for the performance assessment and optimization of energy efficient strategies of managing the indoor air quality (IAQ) in new and existing residential buildings.

The energy performance of new and existing residential buildings needs to be radically improved to meet ambitious climate change goals and residential buildings are by far the largest component in the total building stock. A central boundary condition in constructing energy efficient buildings is doing so while maintaining a healthy, acceptable and desirable indoor environment. While ventilation is the main strategy that is adopted for IAQ management, other technologies influencing IAQ (e.g. air filtration) are available as well and a large number of ventilation strategies exist. There is, however, no coherent assessment framework to rate and compare the performance of IAQ management strategies. The annex therefore focuses on assessing the performance trade-off between and identifying the optimal solutions for maximizing energy savings while guaranteeing a high level of indoor air quality in new, renovated and existing residential buildings.

To achieve this, the annex gathered the existing scientific knowledge and data on pollution sources in buildings, looked at the opportunities that spring from the rise of IoT connected sensors, studied current

and innovative use cases of IAQ management strategies and assessed the continuous performance of the implemented IAQ management strategies over their lifetime.

In the annex, experts from different fields including mechanical engineering, building science, chemistry, data science and environmental health worked together with other stakeholders towards consensus on the basic assumptions that underlie such a performance assessment and practical guidelines and tools to bring the results to practice.

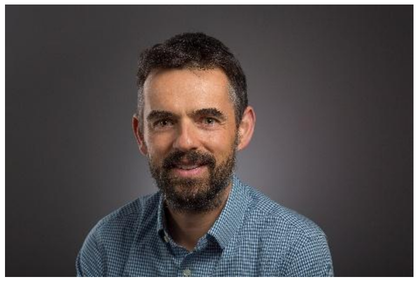
The goal is to accelerate the development of better and more energy efficient IAQ management strategies to address rapidly changing expectations of the home environment due to challenges such as peak oil, climate change or pandemics. In this presentation, we will look at the main results of the Annex as either an assessment method or a rating ecology and discuss the merits of either approach.

Keywords:

IAQ management, Rating, Assessment, Ventilation, Smart materials

Iain A Macdonald

National Research Council (NRC), Canada



Bio:

Dr Iain A Macdonald is a senior researcher and team lead of the Integrated Building Performance group at the Construction Research Centre of the National Research Council (NRC), Canada. He has researched and published widely in the area of building simulation on such aspects as daylighting, renewables integration, IAQ, ventilation and building energy use. Iain's main research activities are on the assessment of uncertainty in building simulation with a focus on high performance building design support. He is currently the technical lead for the Net Zero Energy Research project which is developing the supporting evidence to enable net-zero (energy and carbon) building codes for Canada.

Prior to joining NRC in 2006 Iain was a Senior Research Fellow at the Energy Systems Research Unit (ESRU) in Strathclyde University, Scotland. Iain was responsible for the delivery of the IBPSA Scotland technology transfer project which supported engineering and architectural practices in developing in-house simulation capabilities, thus increasing the impact on design through the use of advanced building simulation tools by design professionals. Additionally, for ESRU he managed many consultancy projects principally in the area of daylighting and natural ventilation.

Presentation Title:

Net Zero Energy Codes in Canada

Abstract:

Canada's National Model Codes, developed by the Canadian Board for Harmonized Construction Codes with support from the National Research Council, are adopted and enforced by local authorities across Provinces, Territories, and other jurisdictions. Since 2015, these Codes have expanded their energy provisions to include a set of performance Tiers, offering a clear path toward 'net-zero energy.' This approach reduces uncertainty and allows jurisdictions to enforce the Tier that best aligns with their specific goals and circumstances.

The 2025 Codes will introduce requirements for greenhouse gas (GHG) emissions from building operations via a set of GHG Levels, analogous to the existing energy Tiers. Given Canada's diverse energy landscape, the Energy Tiers and GHG Levels are designed independently, providing jurisdictions with the flexibility to choose their pathway toward 'net-zero' goals.

This dual focus on energy and carbon performance metrics requires robust simulation support to ensure proposed changes are both effective and economical for industry. Assessments involve simulations of 240 residential and 16 commercial/multi-family building archetypes across up to 33 Canadian locations. These simulations evaluate the impact of proposed code changes and assist in developing prescriptive requirements suitable for most buildings.

The presentation will present the assessment process with examples of infiltration and ventilation, highlighting challenges posed by code limitations, modelling assumptions and their impact on assessments.

Keywords:

Building Codes, Energy, Operational GHG Emissions

James A. McGrath
Maynooth University (MU), Ireland

Bio:

Dr McGrath (BSc, PGDip, PhD, CPhys) is an Assistant Professor at Maynooth University (MU) and a member of MU's ICARUS Research Institute and the Kathleen Lonsdale Institute for Human Health Research. His research encompasses both fundamental and applied studies in the field of the indoor built environment, focusing on indoor environmental quality, aerosol science, and building ventilation. Dr McGrath's recent work explores the energy-health nexus in the context of climate change, particularly the implications of large-scale national retrofits in residential and public-sector buildings, such as offices and schools. He is the principal investigator of several ongoing IAQ monitoring projects, which examine the impacts of energy poverty and retrofit scenarios. He has over 80 research publications, including journals, conference proceedings/abstracts, and technical reports. He currently serves on the Board of Directors for the International Society of Indoor Air Quality and Climate (ISIAQ) and represents Ireland on the Air Infiltration and Ventilation Centre (AIVC) Board. His research has garnered over €2.6 million in funding from agencies such as SEAI, EPA, and SFI, either as PI or Co-PI. Dr McGrath is also an Associate Editor for the International Journal of Ventilation and has been an invited expert advisor for the revision of NSAI S.R. 54 'Code of Practice for the Energy Efficient Retrofit of Dwellings'. He has extensive experience in public outreach, playing critical roles in scientific outreach at high-profile events, and regularly engages with various media outlets (TV, radio, and print).

Presentation Title:

Indoor Air Quality in Naturally Ventilated Classrooms and Offices

Abstract:

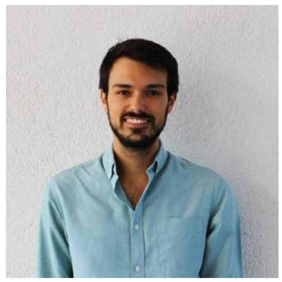
Air pollution significantly affects global health, accounting for one in ten deaths worldwide. Schools represent crucial environments due to children's extended exposure and increased vulnerability to air pollution. The detrimental effects of poor indoor air quality (IAQ) in offices and classrooms are well documented, including chronic and acute health issues, reduced attendance rates, impaired academic and work performance, decreased productivity, and substantial socioeconomic consequences. Ventilation is essential for maintaining IAQ and thermal comfort by regulating the exchange of indoor and outdoor air. While numerous IAQ studies in offices and classrooms have focused on mechanically ventilated buildings, the effectiveness of natural ventilation in these environments is less extensively documented. The current study aims to characterise the spatial and temporal variation of key indoor air pollutants in naturally ventilated classrooms and offices, concentrating on identifying the primary building and occupancy-driven factors influencing IAQ. This study involved multi-zone IAQ monitoring in 2-4 locations across 17 buildings in Ireland, consisting of offices and classrooms, totalling 51 environments. $PM_{2.5}$, CO_2, temperature, relative humidity, and total volatile organic compounds were measured in real time over a week. Formaldehyde, BTEX, pinene, limonene, and NO_2 were collected through passive samples over a week, except for NO_2, which was measured over three weeks. Distinct patterns emerged between offices and schools, with CO_2 concentrations in classrooms being nearly double those found in offices during occupied periods. $PM_{2.5}$ and NO_2 concentrations were significantly influenced by ambient pollution, with $PM_{2.5}$ showing a strong correlation ($r=0.75$). Furthermore, 48% of monitored days surpassed the WHO 24-hour guidelines. Median formaldehyde concentrations were 19 $\mu g/m^3$ in offices and 20 $\mu g/m^3$ in classrooms, higher than the standards observed in previous studies. Significant spatial variation was noted both between and within buildings, with certain pollutants exhibiting greater variability within buildings than between them. Both indoor and outdoor temperatures were key factors influencing ventilation behaviour, particularly in classrooms, where lower temperatures were linked to elevated CO_2 concentrations. The results highlight the ongoing challenges in balancing thermal comfort, ventilation, and IAQ. These insights can inform policy development in naturally ventilated offices and schools, enabling evidence-based strategies to minimise exposure to indoor air pollution and enhance occupant health and well-being.

Keywords:

Schools, offices, particulate matter, formaldehyde, CO_2

Marco Morini

European Commission, Directorate General for Energy, Unit ENER B.3 Energy Efficiency – Building and Products



Bio:

Marco Morini is a Building Engineer and PhD in Building Technology. Since February 2023, he works as a Policy Officer in the Buildings and Products Unit in DG ENER, where he deals with several topics entailing buildings energy efficiency and the Energy Performance of Buildings Directive (EPBD), including indoor environmental quality and technical building systems. Marco is a Seconded National Expert from the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), where since 2019 he worked as a Researcher in the field of Energy Efficiency in Buildings. His role entailed the provision of technical Support to the Ministry of Ecological Transition on Building Energy Efficiency Policy as well as research and technical activity about Energy Efficiency, Building Renovation, and Building Information Modelling.

Presentation Title:

Addressing Indoor Environmental Quality and inspection of ventilation systems: provisions in the EPBD Recast

Abstract:

The recast Energy Performance of Buildings Directive (EPBD) of 2024 includes new requirements concerning technical building systems, expands the scope of the inspections for HVAC systems, and addresses comprehensively Indoor Environmental Quality in both new and existing buildings. Some elements of the non-binding guidance documents that the Commission is developing to support Member States in implementing these provisions will be presented.

Keywords:

EPBD, Buildings, Indoor Environmental Quality (IEQ), Indoor Air Quality (IAQ), Ventilation

Bassam Moujalled

Cerema, France

Bio:

Dr. Bassam Moujalled is a researcher in the research team Performance of Buildings in their Environment at Cerema, the French public agency specializing in public expertise for ecological and energy transitions.

He holds two master's degrees in civil engineering, earned between 2001 and 2002. In 2007, he obtained his Ph.D. from INSA Lyon, where he focused on modeling adaptive thermal comfort in naturally ventilated buildings. Following a two-year postdoctoral fellowship, he joined Cerema in 2009 as a researcher specializing in building performance. His research interests include the overall performance of ventilation systems and building airtightness, the characterization of thermal comfort in relation to occupant behaviour and building resilience in the context of climate change.

He is the co-author of more than 60 articles in international journals and conferences. He also co-supervises postdoctoral and Ph.D. theses and has actively participated in numerous collaborative projects in France and Europe.

Presentation Title:

Assessment of the impact of climate change on thermal comfort in buildings, taking account of occupant behaviour and the urban context

Abstract:

With climate change, extreme events such as heatwaves are expected to become more intense and frequent. Overheating will increasingly occur indoors, resulting in severe thermal discomfort in summer or increased cooling demands to mitigate this issue. However, this thermal discomfort can be reduced without relying on energy-intensive air-conditioning systems, by implementing adaptation measures to climate change. For example, using adjustable external solar protection and enhancing ventilation by opening windows are effective solutions where occupant behaviour plays a crucial role. However, the effectiveness of these solutions can be compromised by the urban context, which may both restrict occupants' ability to adapt and intensify urban heat island effects.

Through an approach based on in-situ monitoring and modelling, this paper presents a methodology for assessing the impact of climate change on summer thermal comfort in residential buildings, taking into account the occupants and the urban context. The first part focuses on the generation of meteorological files of the future climate on a local scale and incorporating heatwaves. Secondly, thermal comfort indicators are compared with the actual sensations of occupants using data collected in occupied dwellings in Lyon. Occupant behaviour is then modelled using a machine learning approach. Finally, building performance simulations are used to assess the effectiveness of passive strategies for improving summer comfort under different agent profiles.

Keywords:

Thermal comfort, Occupant Behaviour, In situ measurement, Agent-Based modelling, Heatwave

Dirk Müller

Heinz Trox Wissenschafts gGmbH, Germany

Bio:

Prof. Dr.-Ing. Dirk Müller began his scientific career after studying mechanical engineering at RWTH Aachen University and the Thayer School of Engineering at Dartmouth College. After completing his doctorate at RWTH Aachen, he worked at Robert Bosch GmbH in central research and at Behr GmbH as a process manager for simulation. Since 2003, he has been a full professor at the TU Berlin and headed the renowned Hermann Rietschel Institute until 2007. Since 2007, he has been a full professor at RWTH Aachen University and head of the newly founded Institute for Energy Efficient Buildings and Indoor Climate (EBC) at the E.ON Energy Research Center at RWTH Aachen University. In addition to his research and teaching activities, Prof. Dirk Müller was Chief Technology Officer at TROX GmbH from 2011 to 2015.Since 2016, he has been Director of the Institute of Energy and Climate Research – Energy Systems Engineering (ICE-1) at Forschungszentrum Jülich GmbH in the Helmholtz Association and Managing Director of Heinz Trox Wissenschafts gGmbH. Since 2017, he has been Vice Dean of the Faculty of Mechanical Engineering. In addition, Dirk Müller is Senior Advisor to Viessmann Climate Solutions SE and Chairman of the Energy Advisory Board of the City of Aachen.

Presentation Title:

Solution to Improve IEQ in Classrooms

Abstract:

Many studies in recent years have shown that classrooms in Germany often do not have a satisfactory indoor climate. Although further studies have shown that both the health and the performance of students and teachers can be improved by a good indoor environment, the necessary refurbishment measures are being implemented only very slowly and sometimes with the wrong priorities. In this paper, a new concept for a quick and cost-effective renovation of a classroom is presented as part of an intervention study.

The intervention improved the thermal comfort, the indoor air quality, the lighting situation and the room acoustics. The design of the construction work can be planned with a freely available web tool and the construction work can be implemented in a classroom within a few days. The initial results of

this renovation process are shown based on an evaluation of the intervention experiment and compared with the previously determined values of the IEQ.

Keywords:

Classroom, intervention, thermal comfort, indoor air quality, lighting, acoustics

Bjarne W. Olesen

Technical University of Denmark, Denmark

Bio:

Bjarne W. Olesen, Professor, Ph.D, Dr.H.C., R.1.
Master's degree in civil engineering, 1972. Ph.D., Laboratory of heating and Air Conditioning, Technical University of Denmark, 1975. In the period 1972-1990 Research scientist at the Laboratory of Heating and Air Conditioning. Part time affiliated as product manager at Brüel & Kjaer 1978-1992. Senior Research Scientist, College of Architecture, Virginia Tech. in the period 1992-1993. Since 1993 until January 2004 Head of Research & Development at UPONOR-VELTA GmbH KG & Co., Norderstedt, Germany. Since January 2004 full professor in Indoor Environment & Energy at the Technical University of Denmark and past director of the International Center for Indoor Environment and Energy, Technical University of Denmark. Awarded the Ralph Nevins Award (1982), Distinguish Service Award (1997), Fellow Award (2001) and Exceptional Service Award (2006) from ASHRAE. Honorary member of AICARR (Italy), SHASE (Japan) and VDI-TGA (Germany). Chivalric Order of Dannebrog, from the Danish Queen (2012). Doctor Honoris Causa, Slovak University of Technology
ASHRAE President 2017-18. Andrew T. Boggs Award-ASHRAE 2020, Donald Bahnfleth Environmental Health Award-ASHRAE 2021. ASHRAE president 2017/18
Is active in several CEN-ISO. standard committees regarding indoor environment and energy performance of buildings and HVAC systems. Has published more than 500 papers including more than 150 in peer reviewed journals.

Presentation Title:

Why is PECS not a mainstream product today?

Abstract:

For decades, the use of Personal Environmental Control Systems (PECS) has extensively been studied by many researchers all over the world. There are, however, very few systems installed and used in real buildings. Why is that? The present presentations will discuss some of the hurdles and issues to overcome before it becomes mainstream of the shelve product. As the names say, it is systems that provide individual environmental quality (thermal comfort, IAQ, illumination, and acoustic) under personal control. The most used type of PECS is a personal fan for cooling and a desk lamp for

illumination. The goal is to have PECS that influences two or more of the indoor environmental quality factors. Almost all studies with persons (laboratory or some field studies) show the benefits of PECS regarding acceptable environmental conditions, better individual comfort, and the benefits of personal control. Even studies show increased performance of users. That should support and provide incentives for manufacturers to bring products to market. Very few systems exist on the market. Probably heated/cooled chairs have had the largest market penetration even if it is small.

So what are the obstacles? Costs are certainly a factor. In most office applications, you still need a second general system to condition the space. Even if it can be scaled down, the total price for HVAC may increase. If however, the increase in performance is taken into the economic calculations, the increased costs will be compensated. In practice, one important challenge is to bring the outside air to all workplaces. Either through the general ventilation system or connection directly to the outside.

How big is the market? PECS requires that people have a fixed workplace and are not moving around a lot. Therefore, the focus has been on sedentary work in landscape offices. There may, however, be a future home market. People are in many companies now working at home 2-3 days a week. The companies may therefore cut down on office space. On the other hand, the discussion is if a company then has some responsibility for the working conditions at home. This would be a new market for PECS.

IEA-EBC Annex 87 Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems (PECS) was established a couple of years ago to look at many of these issues and establish a better foundation for developing, testing, and installing PECS in real-life buildings.

The presentation is the opinion of the presenter and not of Annex 87, which are and will in the coming years work with the issue of market penetration.

Keywords:

PECS, Heating, Cooling, Ventilation, Illumination, Acoustic, Control

Christine Roßkothen

Heinz Trox Foundation, Germany

Bio:

Christine Roßkothen is Chairman of the Heinz Trox Foundation.

After completing her training as an industrial clerk and earning a master's degree in business administration as well as and a qualification for teaching at secondary level II with a focus on vocational education, Christine Roßkothen worked for seven years as a consultant in a management consultancy specializing in strategic marketing, with a particular focus on steel and construction products.

In 2002, she joined TROX GmbH as Marketing Manager for the TROX subsidiaries. When she assumed the newly established role of Head of Corporate Marketing in 2005, she successfully developed and expanded the marketing operations of the TROX GROUP. In this role, she was responsible for internal and external corporate communications, operational marketing and the TROX ACADEMY for all target groups, media, communication channels and subsidiaries.

Since 2020, she has been leading the Corporate Social Responsibility division of the foundation-affiliated TROX GROUP, playing a key role in shaping the sustainability strategy of the global market leader.

In addition, she was appointed to the board of the Heinz Trox Foundation in 2019 and has since been responsible for finances and scientific funding in the field of indoor air quality.

The research-focused foundation generates knowledge on indoor air quality in schools and its impact on the health and concentration of both students and teachers.

Presentation Title:

Introduction Heinz Trox Foundation

Abstract:

The Heinz Trox Foundation, established in 1991, reflects the life's work of its founder, Heinz Trox, and ensures that TROX GROUP continue to exist as an independent company. The purpose of the foundation is to promote scientific activities in the field of air conditioning and ventilation technology and to support social and cultural activities.

The Heinz Trox Foundation extends its research efforts through the Heinz Trox Wissenschafts gGmbH, located in Aachen. Together, they are dedicated to studying indoor air quality in schools and its effects on the health and concentration of both pupils and teachers.

In addition to supporting research, the foundation is dedicated to science communication and spreading awareness about maintaining healthy and sustainable indoor air quality.

Keywords:

Heinz Trox Foundation, Indoor air quality

Lukas Schmitt

Technische Universität Berlin, Germany

Bio:

Lukas Schmitt M.Sc. studied Business Administration and Engineering at RWTH Aachen University (2012-2018). He has been a research associate at the Hermann-Rietschel-Institut, Technische Universität Berlin since 2019. In 2024, he took over the lead of the Indoor Environmental Quality (IEQ) research area. His research focuses on the development of innovative ventilation strategies, the optimization of indoor climate concepts and the implementation of energy-efficient building standards.

Presentation Title:

Smart IAQ Management: Enhancing Energy Efficiency in Partially Occupied Office Buildings

Abstract:

Indoor air pollution arises from multiple sources, including both the building itself and its occupants. Building materials, furnishings, and office equipment continuously emit a range of volatile organic compounds (VOCs), which can contribute to adverse health effects and discomfort among building occupants. Additionally, the activities of occupants themselves impact indoor air quality (IAQ) through the release of bioeffluents, with carbon dioxide (CO2) commonly used as a key indicator of air quality. We conclude: Indoor pollutant levels are influenced by both the number of occupants and the size of the ventilated space.

The importance of IAQ extends beyond health concerns, as it directly influences the comfort and productivity of individuals within office buildings. However, achieving optimal air quality often requires increased ventilation rates, which can be at odds with stringent energy efficiency policies. This challenge has become more pronounced in recent years due to evolving workplace dynamics, such as the widespread adoption of hybrid work models, flexible office arrangements, and shared desk usage patterns. These trends have introduced significant variability in building occupancy rates, rendering traditional HVAC system designs – often based on static assumptions about occupant density – insufficient for effectively managing IAQ and energy consumption.

To address this issue, we propose a novel approach aimed at enhancing ventilation efficiency by optimizing occupant navigation and dynamically reducing the ventilated area during periods of partial

occupancy. By strategically concentrating occupants in specific zones of a building and adjusting ventilation accordingly, it is possible to lower pollutant loads associated with building materials and furnishings while still maintaining acceptable IAQ levels. This method offers a promising solution to the ongoing trade-off between energy efficiency and indoor air quality, particularly in modern office environments where occupancy fluctuates significantly.

Our approach was evaluated using a computational simulation model that integrates airflow dynamics with thermal heat transfer analysis. This model was applied to a representative office floor layout, reflecting typical occupancy patterns. A parameter study was conducted, focusing on scenarios with 50% occupancy and varying boundary conditions, to assess the potential energy savings. The findings indicate that thermal energy consumption can be reduced by an estimated 5% to 15% through optimized occupant distribution and targeted ventilation control, without negatively affecting perceived indoor air quality.

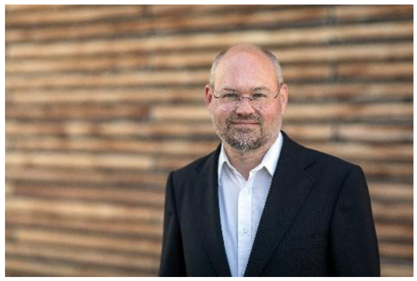
These results highlight the potential for substantial energy efficiency improvements in office buildings, particularly during periods of reduced occupancy. By reducing the ventilated space per person while maintaining adequate air exchange, energy consumption can be minimized without compromising IAQ. Furthermore, ensuring that occupancy remains closer to the design capacity of the building helps stabilize key IAQ performance indicators, reducing the frequency of ventilation control adjustments and enhancing overall system efficiency.

Keywords:

Indoor Air Quality, Ventilation optimization, Occupant navigation, Energy efficiency, Partial occupancy

Andreas Schmohl

Fraunhofer IBP, Germany



Bio:

Andreas Schmohl is a chemist with a broad background in natural sciences. He completed his studies in chemistry at the University of Heidelberg with a degree in chemistry. He continued his studies in Heidelberg, completing his doctorate in 2004 in the field of physical chemistry and, to gain specialized knowledge, a postgraduate program in "Toxicology and Environmental Protection" at the University of Leipzig from 2002 to 2005.

Following this, he worked several years as a freelancer providing scientific services. Since 2011, he has been a research scientist at Fraunhofer IBP, where he applies his expertise in air and water analysis, material emission testing, mathematical evaluation models, computer-aided simulations, and toxicological risk assessments. He likes to combine his theoretical knowledge with his practical experience. He contributed to standards and authorization procedures and, in recent years, to publications on the subject of data evaluation for efficiency investigations of air purification systems.

Presentation Title:

Concepts of air purification efficiency tests under realistic conditions with continuous bioaerosol source and evaluation of the test results

Abstract:

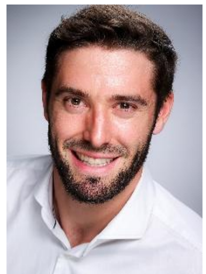
Air purification technologies have become significantly more relevant since the outbreak of the Sars-CoV-2 pandemic, especially in naturally ventilated but highly frequented indoor environments such as schools and cinemas. In addition to filtering technologies, inactivating air purifiers using e. g. ultraviolet radiation or cold plasma gained higher relevance. The cleaning efficiency of air purification systems is usually tested by measuring an exponential decay under well mixed conditions without dosing during the measuring period. Due to the complexity of real applications, important aspects and properties of the cleaning systems remain unanswered by these simple tests. The test results are often combined with indoor ventilation simulations. In our opinion, there is a lack of studies, particularly for the removal of airborne microorganisms, which divide the leap from such decay measurements to computer-aided simulations of the purification effect under real conditions into several steps. To obtain application conditions as close to reality as possible, tests were carried out with continuous bioaerosol dosing in

test rooms and facilities ranging from 12 m³ to 130 m³ under controlled indoor climatic conditions, including office, aircraft cabin, and ventilation duct. Various air purifiers, e.g. standalone devices, wall- and ceiling-mounted units, and induct systems were examined. A suspension containing Phi6 bacteriophages as a surrogate for a pathogen virus was nebulized continuously into the test facilities while air exchange and mixing conditions were modified. To measure the spatial characteristics of the cleaning effect in a room, no additional air mixing was carried out in addition to the cleaning system under analysis. This setting can be used to detect a short-circuit airflow that increase the risk of infection for people in the vicinity of the source of the pathogen. Due to the continuous bioaerosol dosing, it was necessary to develop a mathematical model (named “incremental evaluation model”) to evaluate the data. The main parameters of the model, in addition to the switching times of the devices, are the source term and the exponential loss constant of the air purification system (kAC) and the loss constant without air purification system. The higher the value of the parameter kAC, the better the cleaning effect. Under steady state conditions, the source term can be assumed as constant. For more sophisticated investigations, these parameters were determined temporally and spatially resolved. Based on the test results of selected highly frequented indoor spaces with different ventilation and cleaning scenarios, a calculation tool (VEPZO model) was developed to determine the concentration distribution of active airborne microorganism in real rooms. Advantages, challenges, solutions and outlook of investigations and evaluation tools of air purification systems with continuous bioaerosol source under realistic conditions will be presented.

Keywords:

Hygiene concept, air purifier, indoor air quality, evaluation model, bioaerosol

Lukas Siebler
University of Stuttgart, Germany



Bio:

Lukas Siebler has been a research associate at the Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) at the University of Stuttgart for 7 years. He decided to pursue a technical career back in 2010 when he started his bachelor's degree in mechanical engineering. After an internship in gearbox development at the car manufacturer Mercedes-Benz, he continued his Master's degree in vehicle and engine technology in 2014, focusing on the thermodynamics of diesel engines.

In 2017, after successfully graduating, he decided against further research in the field of combustion engines. Instead, he was able to establish himself in the field of energy technology at the Institute of Building Energy, Thermal Engineering and Energy Storage at the end of 2017.

He has been working on HVAC projects here from the very beginning and has been deputy head of the Indoor Climate Technology working group since 2021. With this group, they were the first research team to measure the risk of infection in indoor spaces during the SARS-CoV-2 pandemic and to develop additional stochastic models. In general, they are researching healthy and comfortable conditions in indoor spaces. They deal with the physics of efficient ventilation processes, the analysis of infection processes and the evaluation of thermal comfort. All these areas must be accompanied by the lowest possible energy consumption.

In addition to classic indoor climate technology, he is enthusiastic about the thermodynamics of humid air and is currently completing his doctorate in this field.

Presentation Title:

Indoor Climate in the Spotlight: Between Health Protection and Energy Efficiency

Abstract:

Indoor air quality has gained increasing attention as a key factor in safeguarding occupant health. At the same time, ventilation systems account for a significant proportion of a building's overall energy consumption. On the health-protection side, current findings highlight the importance of reducing infection risk, maintaining comfortable temperature and humidity levels, and effectively reducing pollutants. Equally vital is the need to conserve resources by deploying demand-controlled ventilation, leveraging heat-recovery technologies, and optimizing air-distribution designs. Taken together, these

parallel research fields underscore the fact that a healthy indoor climate and energy efficiency cannot be treated as competing priorities; instead, they must be addressed jointly. By balancing health-driven demands with low-energy solutions, modern ventilation concepts can achieve sustainable, high-performance indoor environments for all. This presentation spotlights these two crucial areas of research – health protection and energy efficiency – to illustrate how ventilation strategies can safeguard indoor air quality while minimizing energy use.

A promising approach to ventilation strategies involves using CO_2 concentrations as an indicator of the infection risk and dynamically adjusting the volume flows based on real-time conditions. In this model, an algorithm calculates an optimal CO_2 target by weighing the costs of employee absences due to potential infections against energy costs for increased ventilation. In case of high transmissibility or vulnerability of viral pathogens, for example, air handling units automatically lower the CO_2 setpoint to reduce the infection risk - which leads to higher air exchanges and slightly higher energy consumptions. Conversely, if the risk of infection is categorised as low, slightly higher CO_2 values are set, while complying with further parameters of indoor air quality, which saves energy without significantly affecting health.

By integrating these factors into a single, monetary-based indicator, the historically static Pettenkofer value (defined as 1000 ppm) becomes a dynamic parameter. This shift not only aligns indoor air quality measures more closely with economic realities, but it also paves the way for adaptive and future-oriented ventilation strategies, heralding a new era in indoor climate technology.

Keywords:

Ventilation Strategies, Public Health, Infection Risk Assessment, Energy Efficiency, Ventilation Effectiveness

Pawel Wargocki

Technical University of Denmark, Denmark

Bio:

Pawel Wargocki is a professor at the Technical University of Denmark. He is an ISIAQ, REHVA, and ASHRAE Fellow. He is an academic teacher, scientist, industry consultant, and IAQ expert. He is a mechanical engineer by education. He has expertise in environmental psychology, physiology, and exposure monitoring and more than 30 years of experience in research on human requirements in indoor environments. He graduated from the Warsaw University of Technology in Poland and received his Ph.D. from the Technical University of Denmark, where he has been teaching and performing research ever since. He is known for his seminal work demonstrating that poor indoor environmental quality affects the performance of office work and learning. This and other research work influenced requirements for ventilation and air cleaning. Recent research includes studies on human emissions, sleep quality, the development of IEQ rating schemes, the performance of green buildings, solutions for reducing infection risk and air cleaning, and interactions between different indoor environmental domains. He has trained and educated numerous students and scholars. He has collaborated with leading research institutions, universities, and industrial partners worldwide, such as the National University of Singapore, Jiao Tong University in Shanghai, Syracuse Center of Excellence, United Technologies, Velux, Boeing and Google. He was President and long-standing board member of the International Society of Indoor Air Quality and Climate (ISIAQ), President of the ISIAQ Academy of Fellows (previously Academy of Indoor Air Sciences), Vice President of the Indoor Air 2008 conference, and Chair of several ASHRAE committees. He has been invited to many conferences to give a plenary talk and received several awards for his work, including the Rockwool Award for Young Researchers, the ASHRAE Ralph Nevins Award, ISIAQ's Yaglou Award, and the Indoor Air Journal Best Paper Awards. He published extensively (h-index=56).

Presentation Title:

The TAIL rating schemes for offices and schools are the way to reduce carbon emissions and improve IEQ

Abstract:

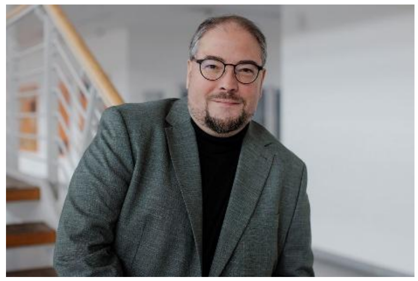
The rating scheme for indoor environmental quality (IEQ) will be presented. It is called TAIL. It creates the framework for rating IEQ and its components: thermal acoustic and luminous environments and indoor air quality. TAIL is an integrated rating first developed for buildings undergoing deep energy renovation. It can now be used for any building, including offices, schools, and hotels. TAIL complements the existing approaches for assessing IEQ and complies with the major certification schemes. All components of the TAIL are treated equally - to achieve a high-quality level, all components of the TAIL must be at a high level, and no compromises are accepted. TAIL is based on measurements of ten parameters, observation of one, and simulations of one; 14 parameters are monitored for schools. TAIL has been used in measuring campaigns and has been shown to be an effective tool for demonstrating indoor environment quality. Because TAIL is a performance metric used in buildings under operation, a tool was developed called predicTAIL allowing estimation of IEQ at the design stage. It uses similar principles as TAIL but cannot be used to rate IEQ in the building that is in use. So, it gives an indication of how the design decisions may affect the level of IEQ. Attempts were recently made to supplement the objective measurements with subjective evaluations made by the building occupants to achieve a holistic view of IEQ in a building. The results of these attempts will be presented as well.

Keywords:

Thermal Comfort, Acoustic Comfort, Visual Comfort, Ventilation, Benchmark

Ulrich M. Zissler

Technical University of Applied Sciences Rosenheim, Technology Transfer Center for Building Biology, Airway and Indoor Health; Universities of Giessen and Marburg Lung Center, German Center for Lung Research (DZL), Germany



Bio:

Prof. Dr. Ulrich Zissler is a distinguished researcher in the field of molecular medicine and allergy research with a research focus on the interaction between the built environment and respiratory health. After completing his doctorate at the Goethe University Frankfurt am Main (2012) and his diploma in biology at the Ludwig Maximilian University of Munich (LMU) (2008), he habilitated in molecular medicine at the Technical University of Munich (TUM) in 2024.

In 2025, he became the first professor in Bavaria to be appointed to the Max Aicher Endowed Professorship for Building Biology, Respiratory and Residential Health and as the director of the institute at the Rosenheim University of Applied Sciences in an excellence procedure. He is also the director of the Institute for Technology Transfer in Building Biology and Healthy Housing and an associated researcher at the Lung Center of the Universities of Giessen and Marburg. Prior to that, he worked for over a decade as a postdoctoral fellow at the Center for Allergy and Environment (ZAUM), TUM's Klinikum rechts der Isar, and at the Institute for Allergy Research (IAF) at the Helmholtz Center in Munich. Since 2018, he has been a principal investigator at the German Center for Lung Research (DZL). Prof. Zissler has received numerous prestigious awards, including the Joachim Ganzer Research Prize (2021).

Presentation Title:

Impact of indoor air quality on health

Abstract:

Indoor air quality affects health at the molecular level by inducing oxidative stress, inflammation, epigenetic changes and hormonal disruption. At the same time, it shapes the human microbiome and influences immunity, respiratory health and systemic metabolism. Strategies such as improved ventilation, air purification and exposure to microbial diversity (e.g. in natural environments) can mitigate these risks.

The lecture will emphasize the impact of indoor air quality (IAQ) on human health, with a special focus on indoor air pollutants – such as volatile organic compounds (VOCs), particulate matter (PM), microbial

toxins and allergens – that can trigger molecular responses at the cellular level. Pollutants such as fine inhalable particles (PM2.5) and reactive oxygen species (ROS) induce oxidative stress in lung epithelial cells. This results in epithelial barrier damage and activation of stress-responsive genes that regulate inflammation and antioxidant responses. Long-term exposure to indoor contaminants such as mold toxins alters DNA methylation and histone modifications and can potentially affect gene expression related to immune function, respiratory disease, and even neurodevelopment. In addition, pollutants activate cytokine signaling pathways, leading to chronic inflammation associated with asthma, allergies, and other respiratory diseases. Furthermore, poor indoor air quality alters the composition of the indoor microbiome, causing pathogenic microbes to increase and beneficial commensals to decrease. This dysbiosis is associated with asthma, allergies and chronic respiratory infections.

Keywords:

IAQ, airway epithelial barrier, pollutants

Liang Grace Zhou

National Research Council of Canada, Canada

Bio:

In 2007, Liang Grace Zhou received her PhD in Building Engineering at Concordia University. Grace joined the Ventilation and Indoor Air Quality Group of the National Research Council of Canada (NRC) as a research officer in 2008. At the NRC, Dr. Zhou accomplished projects for Canada's Clean Air Agenda, 2007–2011, and verified ventilation solutions for a field study of asthmatic children in Quebec City.

Since 2011, Grace has led the research and development activities and product evaluations related to radon prevention and control in buildings. She led her team in developing the world's first radon control fan leakage test rig, the world's first Radon Infiltration Building Envelope Test System, and Canada's first Radon Diffusion Test Chamber. These facilities positioned Canada at the forefront of this field and sets NRC apart by being able to evaluate all relevant radon-control approaches. Subsequently, she expanded NRC's research capacity to promote the uptake of verified radon control technologies and ensure requirements relating to radon control are appropriately incorporated in national building codes, standards, and International Atomic Energy Agency guidance documents.

Since April 2021, she has been leading research related to ventilation and control of infectious aerosols at the NRC Construction Research Centre. She has led projects and activities to support broader efforts by the Government of Canada to reduce spread of COVID-19, characterize the distribution of respiratory aerosols and assess the efficacy of HVAC technologies to reduce exposure to airborne pathogens, guide the industry to develop and demonstrate innovative technologies, and contribute to the development of ASHRAE standard 241.

Grace is now a Director Research and Development of Building Performance and Quality unit at the NRC Construction Research Centre.

Presentation Title:

A controlled intervention study in two schools: impact and benefits of the air cleaning measures implemented

Abstract:

The use of portable air cleaners (PACs) in public settings has increased as a preventative measure since the COVID-19 pandemic. A Canadian provincial government initiated a collaboration with the

Ventilation and Indoor Air Quality (IAQ) team of the National Research Council of Canada (NRC) to conduct a controlled intervention study in 2 schools. The goal of the study was to determine the effectiveness of PACs in reducing indoor air contaminants and benefiting the health of students and staff. The study examined the presence of particulate matter of 1-, 2.5-, and 10-micron diameters (PM1, $PM_{2.5}$, and PM_{10}), carbon dioxide (CO_2), target viruses and bacteria, and sick days reported by staff and students under various operating conditions to determine if PACs could make a statistically significant difference in these IAQ and health indicators. The concentrations of PM_1, $PM_{2.5}$, and CO_2 measured between April and June 2023 were presented at the 43rd AIVC - 11th TightVent & 9th venticool Conference and published in REHVA Journal in 2024. This presentation will provide an overview of the study methods with additional findings: 1) The indoor CO_2 concentrations were primarily dependent on the presence of occupants, the leaks/openings through the building envelope in the space, and the ventilation rates. 2) The advantages and limitations of calculating the ventilation rates based on the decay of CO_2 concentrations in the classrooms after school hours. 3) A particle removal efficiency index was defined and used to assess the effectiveness of filtration in removing particles. Based on the PM_1 and $PM_{2.5}$ removal efficiency results, the PAC units in the intervention school were able to remove some of the particles that entered indoors. 4) Two sampling devices with different flow rates and filter medias were used to detect viruses and bacteria chosen for the student age range. The two sampling devices generated comparable results. 5) The PAC units implemented in the intervention school did not appear to reduce the presence of airborne viruses and bacteria or occupant absenteeism due to illness. The observations from this study will be of interest to researchers, PAC users, practitioners, and manufacturers.

Keywords:

Air cleaning, ventilation, occupancy, particle measurement, CO_2 concentration