COMFORT AT THE EXTREMES

INVESTING IN WELL-BEING IN A CHALLENGING FUTURE

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CATE 2024: INVESTING IN WELL-BEING IN A CHALLENGING FUTURE

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CATE 2024

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Finally, we extend our sincere gratitude to all sponsors, partners, and contributors whose generous support made the successful organisation of this conference possible. The efforts of students, PhD candidates, and young researchers in assisting participants throughout the event were invaluable, creating a welcoming and engaging atmosphere for all.

This conference stands as a testament to the collaborative efforts of academia, government, and industry to advance knowledge and innovation in sustainable and extreme climate design.

Thank you all for making CATE 2024 a truly remarkable and memorable experience.

KEYNOTES SPEAKERS

Magdalena Stefanowicz

Magdalena Stefanowicz is a specialist in sustainable building design at VELUX's Daylight, Energy, and Indoor Comfort group (DEIC) in Denmark. She holds two master's degrees: one in Energy-efficient and Environmental Building Design from Lund University, Sweden, and another in Architecture from the Technical University of Gdansk, Poland. With over 10 years of experience in performance-based building design within the architecture and consultancy business, Magdalena has contributed to better comfort, lower energy use, and reduced climate impact in dozens of projects.

Mario Lovrić

Mario Lovrić is a chemical engineer and data scientist. After obtaining his PhD in computational toxicology, he further specialized in the application of machine learning in life sciences. He holds positions with the Institute for Anthropological Research in Croatia and the Lisbon Council in Brussels. He is the scientific director of the Horizon EDIAQI project.

Hannah Pallubinsky

Hannah Pallubinsky is Assistant Professor at the School for Nutrition and Translational Research in Metabolism (NUTRIM) at Maastricht University in the Netherlands and a member of the Thermophysiology & Metabolism research group there (TherMU). Her research focuses on the effects of temperature, particularly heat, on human physiology, health and well-being. Her work takes place at the intersection of human thermal physiology and the built environment. Recent studies show that regular exposure to thermal conditions (just) outside the comfort zone can induce physiological acclimation, improve thermal resilience and enhance metabolic health. Current and future work is directed at making humans more resilient to thermal challenges, as well as contributing to the establishment of more dynamic, sustainable and healthy indoor environments in times of climate change.

Samuel Domínguez-Amarillo

Samuel Domínguez-Amarillo MSc., PhD., CArch is an Associate Professor and Vice-Dean at the University of Seville in Architectural Engineering, having previously taught postgraduate, master, doctoral and professional degree students in a number of universities. His extensive professional, academic and research experience in the fields of building technical systems, energy efficiency, buildings energy, indoor air quality-comfort and sustainability also includes leading professional training programs for architects, buildings engineers, building managers and construction firms. His European Doctorate gained an Extraordinary Doctorate Award. He has participated in a wide range of national and international R&D projects (Europe, USA, and Middle East), and authored many research publications, focusing recently on architectural-environment control for inhabitants' health comfort and wellness. He has been a guest researcher in different European Universities, and a keynote-speaker and chair of international conferences and is a member of International Research networks as NCEUB. He also acts as a scientific advisor of different technological companies and is a senior consultant in the field of high performance building systems, indoor environmental control, energy management and efficiency of buildings, urban environment, and landscape and also on the development of renewable energy projects, technical feasibility studies, economic feasibility studies and energy integration not only focused on raw efficiency, but on transversal approach with buildings as part of complex energy system.

Jessica Fernández-Agüera

Jessica Fernández-Agüera, Ph.D., is an architect and Associate Professor whose work at the University of Seville. With over 15 years of experience in academia and consulting, she is renowned for her expertise in sustainable design and environmental quality. She serves as the Chief Sustainability Officer for EDIAQI (https://ediaqi.eu/governance), a Horizon Europe project that advances indoor air quality through rigorous, data-driven methods. She is also the editor of the book "Calidad del aire interior en los edificios para el bienestar: estrategias de aplicación prácticas," a comprehensive guide for architects and planners focused on health-centric design. Her innovative work includes contributions to the Covid Risk Tool (www.covidairbornerisk.com), a simulation tool that evaluates airborne disease transmission risk in enclosed spaces, offering essential support for safe and responsive design planning. Jessica's commitment to knowledge transfer to society is also demonstrated in her authorship of children's stories, such as "Jimena's Pink Balloon and Pollution," which aim to raise awareness of environmental issues among young audiences.

Sue Roaf

Sue Roaf is Emeritus Professor of Architectural Engineering at Heriot Watt University in Edinburgh. She is an award winning author, teacher, architect and solar energy pioneer. Her 24 books include: Ecohouse: A Design Guide; Adapting Buildings and Cities for Climate Change; Closing the Loop: Benchmarks for Sustainable Buildings, Energy Efficient Buildings, Adaptive Thermal Comfort and The Ice-Houses of Britain. She Chaired PLEA 2017 conference promoting natural energy buildings (www.plea2017.net), has Co-Chaired the Windsor Conferences on Comfort 1994–2020 (www.windsorconference.com) and the Comfort at the Extremes Conference in Dubai 2019 (www.comfortattheextremes.com). Her presentation on Comfort Justice at COP26 is available on: https://www.youtube.com/watch?v=mbsdb70e4SM

Pablo La Roche

Pablo La Roche is an associate vice president in CallisonRTKL's Los Angeles office and a leader for the firm's Performance-Driven DesignTM initiatives, focusing on sustainable design for the commercial practice group. His expansive portfolio includes sustainable buildings all over the world designed with state-of-the-art tools. A tenured professor of architecture at Cal Poly Pomona University, Pablo is also an accomplished author; he has written more than 130 technical papers for journals and conferences, and his book Carbon Neutral Architectural Design placed in the top ten in Amazon's Energy and Buildings category. He is also past president of the Society of Building Science Educators and chair of the solar buildings division of the American Solar Energy Society.

Christian Schuller

Christian Schuller founded his first company at 22, after graduating from university, and since then, he has participated in the founding and transformation of numerous companies, always in the field of home equipment, especially lighting and ceiling fans. He has extensive experience in manufacturing and distribution across all channels, in more than 20 countries on three continents. Currently, he is embarked on his most important and trascendental mission: managing Sulion aiming to contribute to facing the global climate challenge. Sulion`s goals are revolutionizing climate comfort through ceiling fans and raising awareness worldwide of their significant benefits for sustainability, reducing greenhouse gases, saving energy, and improving comfort.

Holly Samuelson

Holly Samuelson is an Associate Professor at Harvard's Graduate School of Design, where her teaching and research focus on the intersection of building design, human health, and climate change mitigation. Holly leads the Human and Planetary Health Group at Harvard, and her research contributions include over 40 peer-reviewed publications, including a Best Paper awarded by the journal Energy and Buildings. Prior to joining Harvard, Holly worked as an architect and a technical consultant to other building professionals.

Atze Boerstra

He is professor of Building Services Innovation at TU Delft. Since 1996 Boerstra has been director of the research and consultancy firm bba binnenmilieu, an engineering consultancy firm in The Hague specialising in indoor air quality and thermal comfort and its effects on people. He is also a partner at DGMR, the holding of bba. Boerstra is also a member of the scientific advisory committee of CSTB Paris / the Observatoire de la qualité de l'air intérieur (OQAI). As a TU Delft representative, he is affiliated with the Impuls knowledge group of the TVVL (Platform for Man and Technology).

Julio Bros-Williamson

Julio is a Lecturer and Chancellor's Fellow in Net-Zero Buildings at the University of Edinburgh, part of the School of Engineering (SoE). His research focuses on low-carbon performance and the evaluation of new and existing buildings. He uses techniques to measure building envelope performance and post-occupancy evaluation of building users. Julio has experience in the deployment of indoor air quality sensors, and the use of digital tools to create digital twins and living labs of buildings. He has close ties with industry leaders, policymakers and international academic leads all of which are part of his existing and future research. His current work includes the retrofit methods of housing and non-domestic buildings implementing an archetype approach and the use of low-carbon heating technology.

Marta Pelegrín

Marta Pelegrím, Dr. Architect (PhD, University of Seville, 2017), is a Professor of Architectural Design at the School of Architecture in Seville, Guest Professor in the International Master for Advanced Architecture at Frankfurt University of Applied Sciences, and lecturer in Design and Materials at the Architecture Institute of Mainz School of Higher Education.
She serves as Director of Research and Innovation Projects on Retrofitting Postwar Social Mass Housing in Germany (2022-2025) and Principal Researcher in I+D Knowledge Generation Projects and I+D+i Challenges in Research funded by the Spanish State Research Agency (2018-2020 calls).
As co-director of MEDIOMUNDO architects, her practice has received accolades in international competitions, and her work has been published in specialized journals worldwide.

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Prologue

CATE 2024

Comfort at the Extremes: New Thinking on Comfort in a Heating World

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Abstract

Climate tipping points are now being crossed as a result of ever more extreme climate trends and weather events. On the 30th anniversary of the first Windsor / CATE conference in 1994 it is clear that the work undertaken at these conferences has changed not only our understandings of how to achieve comfort in buildings and related standards, but also what are the best design priorities for new and refurbished buildings in the different, difficult and unpredictable future we all face. This paper touches on the scale of the climatic design challenge ahead and the success of the Windsor conferences in moving away from 20th century thinking on comfort. The now dated engineering approach sees comfort as only possible within narrow comfort zones, as a product of machines, sold by the kilowatt hour. The now widely preferred Adaptive Approach understands that comfort results from individual, cultural and climatic factors shaped by building designs and the adaptive opportunities they offer occupants. It is argued that to prepare for more extreme weather events when energy grids can no longer be relied on to power buildings, that designers should aim to create Passive Survival buildings tailored to their regional and local climates. The paper then outlines some of the ways in which the CATE conferences have promoted new thinking on how such buildings can be achieved.

Climate Resilience Buildings and Communities

Chairs: Julio Bros-Williamson / Patricia Fernández-Agüera

Estimating Occupant Density Using Multifactorial Analysis: Insights from the Canadian Housing Survey

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Abstract

This study uses diverse socioeconomic predictors to develop a multifactorial model for estimating occupant density, defined as the ratio of occupants per bedroom. To estimate occupant density, traditional models typically rely on equations including only two variables: the number of bedrooms and the total count of occupants. In contrast, our approach incorporates multiple factors, including household income, geographic region, and demographic characteristics, to provide a more nuanced understanding of housing occupancy.

Using data from the two cycles of the Canadian Housing Survey (CHS) conducted in 2018 and 2021, this research also examines occupant density trends over two distinct periods: before the COVID-19 pandemic, and during and after the pandemic. We aim to identify how these periods have affected housing occupancy patterns and the adequacy of living spaces. The analysis also includes subjective assessments of residents' satisfaction with their living space, offering insights into whether households feel they have sufficient space and bedrooms to meet their needs according to the abovementioned ratio.

Our findings reveal significant variations in occupant density based on socioeconomic factors such as income brackets. By integrating these diverse predictors, the study contributes to a more comprehensive understanding of housing needs and arrangements for different demographics. These insights can inform housing policy and urban planning, ensuring that residential spaces are better aligned with the evolving needs and preferences of households.

The Heat is On: Implications of Extreme Weather on Older Adults' Health and Environmental Safety

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Abstract

Older adults, a population that is rapidly growing across the globe, are more severely and unproportionally affected by extreme conditions, which are expected to be more frequent because of climate change. While much is known about the physiological and possible psychological changes that happen as one ages, very little research has been done in the field of human building interactions, behavior, and how design can impact and improve the quality of life for aging adults.

This paper will explore extreme-weather, older adult health, and safety related findings of a mixed methods study. Researchers interviewed 65 people over the age of 65 and findings reveal meaningful stories, which were shared from individuals living in private organized independent and assisted living care communities in the greater Seattle area. Many older adults move into care settings to meet their physical health and/or social needs as they age, sometimes to be closer to adult children, but oftentimes because they cannot live in their homes anymore. The stories presented here depict the challenges, concerns, and dangerous experiences participants have had through their lifetimes and their residency in the community in terms of safety and comfort in the extremes.

Primary outcomes of this study point to the need to include older adults in the conceptual and pre-design phases of communities, which are designed to serve them, such that the unique experiences and circumstances they face can be thoughtfully considered in the design of a facility meant for this population. Additionally, we discovered numerous examples of buildings, their design, or their interfaces, which inhibited an occupants' ability to use their apartments/spaces as they wish to, let alone safely. Findings point to a shift in how design is approached for this population, especially under extreme conditions.

HeatWatch: A Co-designed Application for Personalised Heat Health Risk Management

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Abstract

Heat stress is the primary cause of weather-related deaths and significantly worsens conditions such as dehydration, heatstroke, and chronic illnesses. Climate change is intensifying heatwaves, making them more frequent, severe, and prolonged. Australia's growing and aging population is exacerbating the problem, as the elderly, children, pregnant women, individuals with chronic diseases, and those in disadvantaged communities are particularly vulnerable to the heat.

Both the public and healthcare professionals have a limited understanding of the health risks associated with heat exposure. This is partly due to a lack of clear and personalized communication about the dangers of heat. Current public health advice often provides generic recommendations without offering practical solutions. Moreover, heat advisories primarily rely on temperature measurements, overlooking crucial factors like humidity, wind speed, and individual vulnerability.

To address the significant gap in personalized heat-related health advice, we developed a free online tool HeatWatch. By considering both environmental conditions and individual factors, HeatWatch empowers users to accurately assess their personal heat stress risk. HeatWatch provides customized, evidence-based cooling strategies that are practical and affordable.

The HeatWatch tool utilises a two-node thermophysiological algorithm to estimate heat stress risk based on environmental and user-specific factors. The tool's user-friendly design was developed through collaborative workshops with government, health, and community partners. Focus groups with over 155 individuals from heat-vulnerable populations helped tailor the tool to their specific needs. A successful pilot in summer 2023-24 attracted over 4,000 users.

HeatWatch is a new approach to heat risk management. By providing tailored recommendations based on individual and environmental factors, it has the potential to reduce heat-related health impacts when implemented on a large scale. We will explore the development of HeatWatch, its application in enhancing public health during heatwaves, and its broader implications for digital health solutions in the context of climate change adaptation.

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My Philosophy: Behavioral Strategies to Reduce Energy Use Under Extreme Conditions

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Abstract

As building energy usage and consumption challenges continue to rise, occupant behavior becomes critical to ensuring and realizing energy goals. Behavior modification programs aim to reduce overall energy use by utilizing incentives and education. We can also use these strategies to increase community awareness and sustainability outcomes. In this way, education can be used as a low to no-cost strategy to increase resilience in both normal and extreme environmental conditions. Drawing from previous research conducted on the topic of education, energy and comfort, we have determined areas of interest and importance to reducing total energy usage. Background information from frameworks and case studies provided our team with a baseline understanding of the unique challenges and concerns regarding tenant behavior in extreme environments. Through our work, we have developed a tenant engagement program that leans on education and behavioral change interventions, along with energy efficient technology to support building occupants. Based on findings from our tenant engagement programs, as well as other case study examples, occupants who have access to educational resources, communal campaigns, and behavioral interventions have been shown to benefit greatly in energy reduction practices. We will present specific case studies to highlight different incentive programs along with educational strategies that promote energy efficiency. In a world where environmental extremes present larger and larger concerns and societal challenges, these findings can be adapted to fit into extreme scenarios. Our approach to engaging with occupants can be adopted by those who reside in extreme environments to help individuals understand strategies and behaviors that they can participate in to reduce energy use while promoting their comfort.

Individual Data Sparsity in Smart Thermostat Big Data: Impacts on Modeling Thermostat Use Behavior Dynamics

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Abstract

This study explores the impacts of the sparsity of individual thermostat interaction data on modeling thermostat use behavior dynamics using a dataset of over 100,000 smart thermostats. In developing a data-driven model of Thermal Frustration Theory (TFT), we investigate the challenges and trade-offs in clustering occupant data to enhance predictive accuracy. Our findings reveal that a single, aggregated model fails to capture the diversity of occupant behaviors, resulting in extremely poor prediction performance. Conversely, excessive clustering exacerbates data sparsity, undermining model reliability. By identifying an optimal clustering strategy, we achieve a balance that significantly improves the prediction of manual setpoint changes during demand response (DR) events, enhancing energy management and occupant comfort.

Contribution of ad-hoc and anticipating occupants to low-energy single-family building performance.

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Abstract

The energy balance of low-energy buildings is relatively much more dependent on occupants than traditional buildings. The energy performance of such buildings depends on the schedule and intensity of internal energy gains linked with building function and user profile, but also on human-building interaction - control and adjustment of ventilation, shading, and heating. This paper presents a simulation analysis in TRNSYS of a low-energy single-family house with two kinds of occupants. Ad-hoc occupants' use of mechanical ventilation is a yearlong, heating system based on a default simple control algorithm, while shading and natural ventilation are used reactively, based on a thermal stimulus. Anticipating occupants every 12 hours set strategy for HVAC operation based on weather forecast: choose between active (heating and mechanical ventilation) and free-running (natural ventilation) mode of building, additionally adjust shading acc. weather forecast. Results are presented by energy and thermal comfort indices, showing a better performance of the anticipating occupancy strategy.

Indoor summer temperatures in 1000 apartments in Denmark

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Abstract

Climate change will result in higher outdoor temperatures and more extreme heat waves. As a consequence, residential buildings will experience higher indoor temperatures and unless the buildings and occupants are able to adapt, this will have comfort and health consequences. In Denmark (and the rest of Scandinavia), the heat waves will probably be much less extreme than in other parts of the world. But buildings in Scandinavia are typically not built to withstand high temperatures for extended periods of time and the population is not used to adjusting the building to mitigate overheating, e.g. by the use of solar shading.

In this paper we have measured indoor temperatures, relative humidity and CO2 concentration in 1000 apartments for up to two years in 5-minute intervals. This will be used to investigate the relationship between indoor and outdoor temperatures in summertime and periods with warm weather. The aim is to estimate how well Danish apartments and their occupants adapt to a warming climate.

How do occupants adapt to the heat in their homes: lessons learned from semi-structured interviews and in-situ measurements in urban dwellings

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Abstract

Summer has become a difficult time of year for people living in cities. Heatwaves have increased in intensity and frequency in recent years, and the situation is not going to get any better with climate change. In addition, the urban heat island effect increases temperatures in the city center compared with the surrounding countryside. City residents are therefore implementing behavioural strategies to cope with the heat, particularly in their homes, where they have more freedom to adapt.

To better understand the occupants' behaviour in their dwellings during summer and heatwave periods, semi-structured interviews were conducted with households of eight multi-family dwellings located in the Lyon metropolitan area, in France, during the summer 2023. A field measurement campaign was also carried out in their dwellings, in order to investigate the relationship between adaptive behaviour and indoor environment.

Analysis of the interviews and the in situ collected data revealed the actions adopted by occupants to reduce thermal discomfort in their dwellings. A distinction is made between typical summer behaviour and strategies implemented during extreme heatwave periods. The constraints restricting adaptation actions are highlighted, whether they are personal, internal to the dwelling or external (in particular linked to the urban context). A focus on the use of windows, solar protection and fans is provided.

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Towards scalable smartwatch-collected subjective data collection for environmental comfort at the city-scale

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Abstract

Despite extensive research in thermal comfort, predicting individualized preferences in a field-based, scalable way remains a challenge. In addition, the effects of noise in densely built environments, such as open offices, are relatively under-researched compared to their significance. Understanding noise and thermal comfort is crucial for designing and building sustainable, liveable indoor and outdoor spaces. This paper explores noise and thermal comfort in urban environments utilizing a mixed-methods approach and leveraging wearable technology. The study involves 103 participants using a Micro Ecological Momentary Assessment (micro-EMA/micro-survey) method with Apple Watches. Each participant completed a minimum of 100 micro-surveys on thermal and noise comfort over four weeks across the city scale. Quantitative analyses examine associations between categories in the micro-survey and physiological data. Findings indicate that 28% of participants exposed to high-noise environments report significant noise interference, yet life satisfaction is higher in these settings. Dissatisfaction is lowest in high-noise environments. For thermal preferences, 10% of those preferring cooler conditions are extremely satisfied with their life, while most are slightly satisfied. The study also finds a strong association between location and noise levels and that social settings influence noise levels and thermal comfort preferences. The findings contribute to a nuanced understanding of individual comfort preferences and inform urban planning and design strategies for improved well-being. This research underscores the significance of personalized comfort assessment approaches and the benefits of using wearable technology in urban environments.

Effect on indoor thermal comfort of retrofitting social housing roofs in the Mediterranean climate using a highly emissive radiative cool coating

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Abstract

Social housing built in the middle of the last century in southern Spain is known to suffer from poor thermal insulation conditions that often lead to indoor thermal discomfort and energy poverty. This situation encourages the introduction of improvements through the retrofitting of the envelope to improve the levels of indoor thermal comfort and the associated energy consumption.
In this line, and taking into account the effects of climate change, among which an increase in temperatures is expected, the use of radiative cooling techniques can play an important role in improving indoor thermal comfort conditions, which can be even more significant in the case of the aforementioned social housing.

This paper analyzes the effect on indoor thermal comfort of retrofitting social housing roofs by applying a cool coating consisting of a recently developed ultra-emissive paint with high thermal emissivity levels and low solar absorption value. The analysis is carried out considering as a case study a dwelling belonging to the social building park built in the city of Sevilla, southern Spain, in the middle of the twentieth century. Indoor thermal comfort is evaluated using the adaptive thermal comfort methodology from the ANSI/ASHRAE Standard 55-2020.

The research considered two natural ventilation rates of 0.5 and 1.5 ACH. Results have shown that for the climate under which the study was conducted, the use of ultra-emissive paint is able to substantially reduce the hours of indoor thermal discomfort over a typical climatic year, providing 20.53% and 15.68 % more hours of comfort, respectively, for the ventilation rates of 0.5 and 1.5 ACH.

Examining the relationship between thermal comfort and energy performance in educational buildings

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Abstract

Thermal comfort in educational buildings is very important for protecting the health of students and increasing their productivity. In Turkey, there is a Minimum Design Standards Guide for Educational Buildings prepared by the Ministry of National Education (MEBEYATS) for this purpose. In this guide, the physical parameters that should be in the classrooms throughout the year to ensure the thermal comfort of students (temperature, average surface temperature, humidity and air speed) are specified. However, since the guide does not take into account personal factors (metabolic rate, clothing insulation, etc.) that are important for determining thermal comfort, it falls short in providing thermal comfort. Providing thermal comfort is an important issue not only for ensuring the health of children but also for reducing building energy consumption. To date, minimizing energy consumption for the conservation of energy resources has become one of the first goals in architecture, as in every discipline. Therefore, the relationship between thermal comfort and energy performance in educational structures was examined in the study. For this study, the current state of a primary school building in Adana province was modeled using Rhinoceros software, and thermal comfort analyses were performed using the simulation method using grasshopper ladybug (LB) and honeybee (HB) plugins and the Fanger method, including PVM-PDD indices. The data obtained as a result of the analyses were evaluated according to the MEB Educational Buildings Minimum Design Standards Guide. As a result of this study, it was concluded that the values suggested by the MEB in the guide were insufficient in terms of providing thermal comfort and that thermal comfort values were necessary for a quality and healthy education. This study aimed to expand the scope of the study and obtain values that will guide the guide in future studies.

External thermal insulation retrofitting: A solution for enhancing building thermal performance

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Abstract

Worldwide increasing interest in energy efficiency, sustainability, and global carbon emissions has directed us towards the study that helps decrease the energy consumption in buildings. Thermal insulation retrofitting provides an effective solution for enhancing building thermal performance along with its associated benefits. This paper aims to evaluate the feasibility of thermal insulation retrofitting across the globe through an in-depth review of previous studies. For this, a systemic review of existing research articles was conducted to analyze and extract the relevant details on the performance review of buildings mostly after external thermal insulation retrofitting (ETIR). The data were collected from different climatic zones, building types, and insulation materials. The results from this review have shown a clear connection between thermal insulation and significant improvements in building thermal performance. The results represent the ability of thermal insulation to maintain stable indoor temperature regardless of the outdoor conditions, distinguishable improvement in U-values can be seen at about 70% on average, and energy consumption reduction was found to vary from 14-78%. These outcomes might provide a valuable understanding for the stakeholders and the government relating to the construction and energy sectors to implement ETIR as a feasible solution to address the challenges of climate change and global carbon emissions contributing to sustainable building practices and energy efficiency advancements.

CATE 2024

Thermal comfort of urban park and effect on building energy

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Abstract

Urban parks are vital to urban environments and have a substantial positive impact on people and saves the energy of building. This study conducted field measurement and questionnaire survey to estimate the outdoor thermal comfort and thermal responses of park visitors. Similarly, it also presents the energy saved by building due to the presence of greens on outdoor areas from literature review. 78% of the respondent voted for “4. Neutral” thermal sensation, which shows most of the park visitors feel comfortable during the stay period. The occupant’s comfortable universal thermal climate index (UTCI) of 28ºC was found in the park. From the literature review, it was found that the addition of greenery in outdoor space helps to reduce the cooling load in the building. The study finding may serve as a guideline for the urban planner to design comfortable outdoor space. This helps residents to use the park for different recreational activities during the daytime.

Evaluation of energy efficiency measurement method and thermal environment in data center based on literature review

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Abstract

The increase in data center facilities has led to higher energy consumption and a larger carbon footprint, necessitating improvements in thermal environments for energy efficiency and server lifespan. Existing literature often overlooks categorizing equipment for Power Usage Effectiveness (PUE), criticizing power efficiency measurement methods, and addressing employee thermal comfort. This paper categorizes equipment as either 'facility power' or 'IT equipment power' for PUE calculations, identifies measurement limitations, and discusses employee comfort in various data centers. A comprehensive literature review from 2010 to 2023 was conducted using databases like science direct and Scopus. This review focuses on studies providing data on power consumption, environmental conditions, PUE, DCiE, and employee comfort. Based on several criteria, 78 papers and 27 websites were reviewed. Results show an average Information Technology (IT) power usage of 48.6% and a PUE of 2.06, indicating "average" efficiency. The study highlights a lack of standardization in PUE formula equipment categorization, affecting efficiency ratings. The average indoor temperature and relative humidity in data center were found to be 16.5°C and 19%, respectively, which are uncomfortable for employees. These findings encourage further research to improve energy efficiency and employee thermal comfort.

Socio-Demographic Insights into Urban Building Energy consumption

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Abstract

This study examines the influence of socio-demographic factors on residential energy consumption across different Forward Sortation Areas (FSAs) in Montreal and Quebec City. Residential buildings are critical in the global effort to reduce greenhouse gas emissions, accounting for approximately 40% of energy use and 30% of emissions. While technological advancements such as energy-efficient appliances and improved building materials have been promoted, occupant behavior remains a major factor influencing energy consumption patterns. By employing a data-driven approach, this research integrates hourly energy consumption data from Hydro-Quebec with socio-demographic information from Canadian Census data. The analysis is conducted in three phases: first, feature engineering and ANOVA are used to identify significant socio-demographic predictors of energy use; second, daily energy consumption profiles are clustered using K-Shape clustering to explore distinct consumption behaviors; and third, an XGBoost classification model is developed to predict cluster membership based on socio-demographic features. SHAP analysis is applied to interpret the relative importance of these features in the model's predictions. Results show that factors such as income, employment rate, and household size significantly affect consumption patterns, with notable differences between the two cities. The findings provide insights for policymakers and utility companies to design tailored energy efficiency programs that account for the diversity in energy consumption behavior across urban areas, contributing to more effective demand-side management and energy-saving initiatives.

CATE
2024

Overheating in the Nordics: challenges in the Swedish multi-residential building stock

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Abstract

Overheating has not traditionally been an issue in Sweden and other Nordic countries. However, the record-warm summer of 2018 led to 700 deaths in Sweden, alarming the population and authorities. The Swedish Meteorological and Hydrological Institute projects that extreme heat events, previously occurring every twenty years, may happen every three to five years by the end of the century. This raises concerns for buildings without mechanical cooling, such as homes. The issue of overheating in Sweden requires therefore immediate attention.

To address this, a project was initiated employing a breadth of existing data resources, such as a large dataset of indoor and outdoor air temperature measurements from housing companies. This paper gives an overview of the challenges in the Swedish multi-residential building stock associated with overheating, via literature and statistics review and by analysing selected data from the warmest week in 2023. Data from one housing company were used for an overview (N=925 buildings). Two buildings in the sample were further selected for more detailed examination; one constructed in 1890 and one in 2016.

Among the identified challenges are the lack of requirements for limitation of overheating in new construction and refurbishment, a trend towards smaller and single-sided apartments and potential conflict between addressing overheating and access to daylight, which is highly valued in Northern Europe. Limited thermal adaptation of the Swedish population and sociocultural barriers are also discussed as important challenges.

The data analysis revealed variations in average daily indoor temperature between buildings, with a span of 7ºC (21-28ºC). The case study analysis showed that the 1890s building maintained overall acceptable indoor temperatures during the warmest week, while the 2016 building had a more severe issue. The project's aim is to look at the relationships between different factors and provide short, medium and long-term solutions for new constructions and refurbishments.

The issue of water scarcity and its impact on schoolchildren's comfort and wellbeing

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Abstract

Water scarcity is a lived experience in many locations around the world and is expected to grow with climate change. This issue can affect the students' comfort and wellbeing in ways that have not been described in this context. This study investigated if photovoice is a suitable tool to engage children within this context in describing the issue and share their perspectives on the impact of water scarcity has on their comfort and wellbeing. As well as identifying paths to better this issue.

Photovoice is a method to gather rich and relevant data from subjects that could be difficult to engage with. For the case of children this practice empowers and allows them to express their thoughts and feelings through photographic techniques. This can boost their confidence and encourage them to share their perspectives in ways that might ease the communication while being in a participatory activity. This article is presenting results obtained from one rural school in Valparaiso region in Chile working with a group of children aged 10 to 13 years old. This is the first selected case study out of six rural schools involved in the FSM2395 on-going project. For this, we started with a workshop that included play and photo taking as means to gather data about the impact that water scarcity has on their everyday life at school. Later we conducted sessions where children completed the picture taking exercise and contributed to a structured discussion.

As children were presenting, they were able to identify factors related to water scarcity that influenced their well-being at school and elaborated on how they were affected. They also identified some opportunities to improve their environment. The findings informed the researchers about parameters that could define the problem and possible avenues for improvement. This method proved useful in engaging children and gathering rich information from key subjects that can be difficult to reach otherwise.

Enhancing User Comfort in Hot-dry Climate Dwellings for Future

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Abstract

Future climate projections for Ahmedabad, India, indicate rising maximum temperatures, emphasizing the need for microclimate modifications to enhance indoor comfort. This paper is part of a broader dissertation project, which explores passive design strategies for the 2036 Olympic village in Ahmedabad, focusing on optimizing thermal comfort in residential buildings within a hot-dry climate. *(Gang,2024).*

The study investigates key questions: How can microclimate modifications in residential building forms mitigate rising temperatures? Which courtyard configurations and ventilation strategies are most effective for creating favorable microclimates? Analytical work assesses interventions, including adjusting courtyard height-to-width ratios, optimizing building orientation, and implementing selective ventilation techniques.

At the neighbourhood level, traditional built forms were analyzed to optimize courtyard designs. Using the Universal Thermal Comfort Index (UTCI), the study finds that courtyards with a 2:1 aspect ratio and south-facing orientation are most effective for reducing solar radiation and enhancing wind flow during summer and monsoon seasons.

Rotatable panels in courtyards regulate wind flow, blocking it in summer and allowing it during the monsoon. Thermal simulations of an east-facing bedroom were found to increase comfort hours from 22% in the base case to 95% in the final design iteration.

Exploring Future Passive Habitability of a Canadian Housing Archetype in Different Climate Zones

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Abstract

Climate change-driven extreme weather events such as heatwaves, cold snaps, and rainstorms pose an unprecedented challenge to the built environment. It has been observed that the frequency and intensity of such weather events are increasing. Therefore, buildings must be designed, constructed, and operated in a way that makes them resilient to such extreme weather events.

To this end, this paper aims to explore the passive habitability of a Canadian housing archetype using building performance simulation. Passive habitability is the duration a building remains habitable during a power outage (i.e., when there is an absence of mechanical HVAC) that coincides with an extreme weather event such as a heatwave.

A base case energy model of a Canadian housing archetype was created using DesignBuilder. The housing archetype used in this study is one of the archetypes developed by Natural Resources Canada (NRCan) for developing prescriptive energy code requirements and are intended to serve as statistical representation of the physical and energy-related features of contemporary Canadian housing.
The housing archetype energy model was simulated using current typical meteorological year (TMY) files and projected future TMY files based on 0.5 °C to 3.5 °C increases in the global average temperature in three Canadian climate zones: Zone 4 (Vancouver), Zone 6 (Ottawa), and Zone 7 (Edmonton). Then, the passive habitability of the housing archetype was recorded for each climate zone to assess the resilience of the housing archetype across the three Canadian climate zones.
The results indicated that the shortest passive habitability durations were observed in Edmonton with 1-2 hours duration. On the contrary, the model simulated in Vancouver demonstrated the longest durations of passive habitability with at least 2 hours in the most extreme cases (projected + 3.5 °C increases in the global average temperature). The results of this study indicated that the thermal resilience of housing stock in Canada needs to be investigated and plans need to be put in place to futureproof existing housing in face of climate change-driven weather events.

Indoor Overheating in Residential Buildings

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Abstract

Amidst rising global temperatures, the discrepancy between indoor and outdoor temperature measurements has significant implications for public health research. Most epidemiological studies of associations between heat and mortality or morbidity outcomes utilize outdoor temperature metrics to assess exposures to heat. These may not accurately reflect the indoor environments where adults spend most of their time. This study introduces an approach for assessing exposure to indoor dry and wet bulb temperature and absolute humidity using physics-based energy simulations. We leveraged physics-based simulations and Department of Energy (DoE) and the National Renewable Energy Laboratory (NREL) residential building prototypes to assess summertime indoor thermal conditions across diverse U.S. climate zones. Our approach accounts for varying outdoor temperatures and humidities, including extreme heat events, residential building characteristics, such as roof type, insulation levels, surface area, and different air conditioning (AC) usage levels (100%, 50%, and 0%) on indoor environments. Initial findings from hot humid, hot dry and mixed humid climate zones indicate a relationship between higher outdoor air temperatures and increased indoor temperatures, although values are not the same. While ventilation and air conditioning usage significantly reduce indoor heat, it is less effective during extreme heat waves. Outdoor conditions and air conditioning usage also critically affect indoor weather, with substantial increases observed during heat events, and seasonal peaks in July. Our approach can be used to support the integration of indoor environmental factors into large, geographically diverse, population based epidemiological studies to enhance the accuracy of health risk assessments related to temperature.

Examining Climate Change, Moisture Risks, and Retrofits for Historic Wood Framed Buildings Using Stochastic Simulations

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Abstract

This paper presents research using stochastic methods simulating hygrothermal behavior of wood-framed historic buildings examining moisture risks as climate change progresses. Two cities and three historic assemblies are studied. The two issues that this paper will attempt to address are: (1) A lack of understanding if future weather scenarios will increase risks of degradation for historic wood-framed envelopes, and (2) What are the trends of the moisture risks for historic wood-framed envelopes as climate change progresses? This research employed: (1) Pearson Tukey three-point approximation, (2) hygrothermal simulations using an augmented version of HAM-Tools, and (3) CCWorldWeatherGen for future weather generation. Variables sampled include air infiltration rate, weather years, and starting month. The three wood-framed assemblies (A1-A3) all have exterior wood siding and an uninsulated framing cavity. The three assemblies differ in their interior finishes. A1 has wood lath and plaster for the interior. A2 has wood panels without lath or plaster for the interior. A3 has wood lath, plaster and wood panels. Thermally retrofitted assemblies include a spun bonded polyolefin air/moisture membrane and fiberglass insulation in the framing cavity. Weather years include ASHRAE RP-1325 reference years. Future weather files were created by transforming past weather into 2050 and 2080 scenarios. Results demonstrate that in many scenarios, as climate change progresses the maximum moisture content in the studied assemblies may decrease. However, in some cases, the maximum mould growth increases, even though the maximum moisture content in the wood elements decreases. Insulating these historic wood-framed walls may increase mould growth risks in many cases. This paper demonstrates the benefits of stochastic future weather scenarios to evaluate risks for historic wood-framed envelopes and their potential thermal retrofits. It presents a framework for stochastic evaluation and shows how future envelope behavior may require more investigation.

Impact of shading accessories on summer comfort in attic spaces

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Abstract

Solar shading plays a crucial role in enhancing thermal comfort and reducing the need for cooling energy during summer. In this study, we investigate the impact of interior and exterior shading devices on cooling energy savings and the reduction of indoor temperature during summer.
Our simulations focus on a 3x4m attic room with two roof windows, situated at a 45° south-facing roof pitch, across 29 diverse European cities. The model includes three exterior brick walls and a light-frame roof, with a moderate insulation layers. Two methodologies were employed: one for evaluating cooling energy savings, with mechanical cooler incorporated and another for assessing indoor temperature reduction with ventilative cooling incorporated.
Dynamic building simulations were performed in IDA-ICE software. An extensive parametric analysis covers different shading options, including blackout blinds, awning blinds, soft shutters, and roller shutters. These shading devices were evaluated for both existing roof windows with various types of Insulated Glazing Units (IGUs) and for scenarios where old, poorly insulated roof windows are replaced.
Our results show significant reduction in indoor temperature due to exterior shading accessories across all the studied locations, with an average of 5˚C indoor temperature drop for existing windows and 8.5˚C indoor temperature drop for replaced windows. Notably, the performance of exterior shading varies based on the quality of existing roof windows; the lower the window performance, the greater the impact of shading. In contrast, for replaced roof windows, exterior shading is the most effective upgrade irrespective of the window pane type.
This study quantifies the benefits of the different types of shading across Europe. The insights can guide decision-making about various shading options, contributing to improved thermal comfort in summer. Our research highlights the importance and effectiveness of solar shading in building design and retrofitting strategies.

TOO HOT TO HANDLE? How residents in Nagpur, India are adapting to high summer temperatures

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Abstract

The high summer temperatures being experienced in Nagpur, India have recently presented detrimental health effects and well-being of its residents. This study investigates the lived experiences and challenges faced by two marginalised and underrepresented groups in Nagpur—cycle rickshaw pullers and homeless people. By using a qualitative research method, a greater understanding of the challenges faced at a city level has evidenced the lack of infrastructure and city planning that could mitigate the effects of increased heat waves caused by climate change. The study analysed responses from in-depth interviews with residents to learn more about the coping strategies, health and socioeconomic effects of excessive heat on cycle rickshaw pullers and homeless people. The findings provide insights into resident's adaptability and resilience, contributing to the increasing body of research on social justice and inclusion, human factors in challenging work contexts, and health and well-being in difficult settings. The work also analyses how heat waves have increased in their intensity and occurrence over the years and decades with projections used which should be contemplated for future city planning in India and other Global South locations. Improvements to the infrastructure, sufficient healthcare, and the creation of community-based support networks are all recommended to make urban communities more inclusive and resilient to extreme heat conditions, making sure that the most disadvantaged are not left behind. The knowledge garnered from this study will be beneficial to a more sustainable and equitable approach to managing extreme heat conditions in urban contexts, with an emphasis on the importance of including marginalized voices in the development of policy.

Effect of New Canadian Tiered Building Codes on Thermal Resilience of Housing

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Abstract

In 2020, the National Building Code (NBC) introduced five tiers of energy efficiency requirements for residential and small buildings. Tier 1 is the minimum defined in the previous (2015) edition of the NBC, and jurisdictions can choose higher tiers as their local minimum. Higher tiers are primarily defined by reductions in annual energy use relative to Tier 1, ranging from 10 % at Tier 2 to 70 % at Tier 5. Although promising from an energy reduction perspective, the impact on the thermal resilience of buildings striving for higher tiers within this framework has been a neglected consideration thus far.

As climate change intensifies, occurrences of extreme weather activity are expected to increase dramatically. This means that prolonged blackouts and heat waves are likely to become more frequent, and the possibility of these two situations overlapping is becoming a dangerous human health scenario that needs to be planned for. The new NBC framework encourages energy conservation in buildings, but fails to consider the impact energy conservation measures (ECMs) have on a building's tendency to overheat during a power failure.

This paper introduces a methodology that can be used to analyze the impact of the tiered building code framework on overheating thermal resilience. To show the methodology in practice, ECM packages capable of achieving the above-minimum NBC energy tiers are analyzed using EnergyPlus simulations, and their impact on overheating of a single detached home archetype in Québec City are presented.

Ventilation and Indoor Air Quality

Chairs: Miguel Ángel Campano
/ María Sánchez-Muñoz

Design and performance verification methods for naturally ventilated buildings from the experience of ABC 21 EU Project

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Abstract

The research exposes a critical feedback loop: the building sector's high energy consumption and emissions contribute significantly to climate change. Warming temperatures, in turn, lead to increased reliance on energy-intensive HVAC systems, further exacerbating the problem.
To investigate the potential of passive cooling systems for achieving energy-efficient buildings, the research proposes a methodology for building design and building performance evaluation. Focusing on the interplay between climate, building design, and urban planning, the research plans weather data analysis, measurement campaigns, and structures the design process into four phases favoring advanced natural ventilation.
The design methodology involves:
1. Identifying optimal cooling strategies based on local climate and building typology.
2. Developing a natural ventilation system, potentially supplemented with strategies to increase the ventilative cooling capacity.
3. Optimizing the ventilation solution.
4. Conducting detailed simulations for thermal comfort and energy use.
Additionally, a survey tool applicable to various case studies has been developed. The tool evaluates the feasibility and extent of natural ventilation use and determines the need for mechanical assistance (fans or passive methods) in driving the air flow.
Key findings reveal that while solely relying on natural ventilation might be challenging in hot and humid climates during rainy seasons, prioritizing passive cooling systems remains crucial. The study demonstrates that mechanically assisted natural ventilation can provide sufficient thermal comfort in many cases. Furthermore, strategies like Nocturnal Ventilative Cooling, coupled with a bioclimatic design approach during the planning phase, can significantly reduce the energy demand of HVAC systems.
By highlighting the potential of passive cooling systems for energy-efficient buildings, this research offers valuable insights for architects and urban planners seeking to create sustainable built environments. It underscores the importance of sustainable practices within building design and offers practical strategies for implementation.

Adapting to mixed mode ventilation in the tropics: A longitudinal field study

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Abstract

Mixed-mode ventilation (MMV) offers significant potential for enhancing building sustainability and occupant well-being, addressing the challenge of global warming. However, its real-world implementation in tropical regions is limited due to year-round high temperatures and humidity. Additionally, long-term thermal adaptation studies have primarily focused on outdoor acclimatization, with limited research on how indoor environments shape occupants' comfort perception.

To address this gap, we conducted a 20-week longitudinal field study to examine how tropically acclimatized individuals, typically inhabiting 23-25°C air-conditioned spaces, adapt physiologically and psychologically to an MMV space featuring higher and fluctuating temperatures, humidity, and air speeds. An office space was designed with an incremental cooling strategy, incorporating three operational modes: natural ventilation (NV), localized cooling (LOCAL), and air-conditioning (AC). Weekly post-occupancy evaluation (POE) surveys and bi-weekly physiological measurements were conducted with 28 tenant subjects from the onset of their occupancy.

Our results reveal a 48% reduction in cooling energy use with MMV compared to conventional AC at 24°C. Despite initial low thermal acceptability rates of 56% for the LOCAL mode, a gradual increase over time was observed, reaching 86% after 16 weeks of exposure to the MMV space. The average thermal sensation shifted towards cooler by 0.93 scale unit. This is the first long-term field study on the adaptation effects of indoor environments, demonstrating the feasibility of MMV in tropical climates.

Environmental Quality, Health, and Well-being in Healthcare Spaces for Chronic Patients: A Comprehensive Analysis in a Hemodialysis Clinic

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Abstract

This study characterizes and analyzes the environmental quality of a hemodialysis clinic in Toledo, Spain, focusing on indoor air quality, hygrothermal comfort, acoustic quality, and lighting quality. This work involved in-situ measurements and assessments of various parameters. Measurements were taken twice: once with the controlled mechanical ventilation (CMV) system on and once with it off. Thermal comfort was evaluated using air temperature and Predicted Mean Vote (PMV). Acoustic quality was assessed through noise levels at different times of the day. Indoor air quality was measured by monitoring CO concentration, $_2$ ventilation rates, relative humidity, benzene, formaldehyde, PM2.5, and radon levels. Visual comfort was evaluated based on illuminance and uniformity. Overall, the study provides a comprehensive overview of the clinic's environmental conditions. Finally, technical solutions that improve the indoor environment of this clinical space are proposed.

CATE 2024

School locations in urban areas and their potential impact on indoor air quality

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Abstract

School-aged children are particularly vulnerable to health risks associated with poor air quality, both indoors and outdoors. Regulations focusing on indoor air quality in schools primarily target reducing CO_2 levels through enhanced ventilation to mitigate the presence of indoor pollutants, including viruses. However, in urban settings, outdoor pollutants also significantly impact air quality, affecting both school playgrounds and indoor educational spaces. This study aims to identify distinct clusters among schools based on their proximity to urban environmental factors that influence air quality, either positively or negatively. The city of Concepción in Chile, known for its industrial activities and surrounding green areas, provided the backdrop for this investigation. The study area encompassed 484 schools situated amidst varying degrees of air pollution sources and greenery. Factors influencing air quality included distance to pollution sources ($PM_{2.5}$, PM_{10}, CO, SO_2, and NOx), roads, green spaces, and trees. Distance measurements to these features were standardized and utilized in a k-means clustering algorithm to categorize schools into six distinct clusters. The study's second phase involved validating these clusters through air quality measurements ($PM_{2.5,}$ PM_{10}) conducted across five schools from the main clusters, further substantiating the initial model's efficacy. In conclusion, air quality measurements revealed significant disparities, with Cluster 1 showing lower $PM_{2.5}$ levels, while Clusters 3 and 4 had higher concentrations, especially during peak traffic hours. These findings validate the model, although a larger sample size is needed for further refinement.

CATE 2024

Evaluation of cytogenotoxicity of benzo[b]fluoranthene and benzo[ghi]perylene alone and in a binary mixture using human primary blood cells: preliminary results

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Abstract

Polycyclic aromatic hydrocarbons (PAHs) comprise a class of various organic compounds, which are becoming widespread environmental pollutants mainly due to anthropogenic sources of pollution, involving the incomplete combustion of organic materials, and natural releases resulting from volcanic activity and wildfires, and are readily found in indoor spaces. International Agency for Research on Cancer (IARC) has categorized many PAHs as recognized or suspected carcinogens and mutagens. For instance, benzo[b]fluoranthene (B[b]F) is classified as possibly carcinogenic to humans (Group 2B), while benzo[ghi]perylene (B[ghi]P) is still unclassifiable regarding its carcinogenicity to humans (Group 3) due to insufficient evidence. The carcinogenic and mutagenic potential of PAHs primarily stems from their ability to bind to DNA, which is why we investigated the possible cytotoxic and genotoxic effects of exposure to B[b]F and B[ghi]P, focusing on individual compounds and their binary mixture in a range of concentrations (0.00001 – 10 µg/mL) using human primary blood cells *in vitro* after 4- and 24-hour treatments. Based on the viability assay using differential staining, both B[b]F and B[ghi]P displayed dose- and time-dependent cytotoxicity that was more pronounced after the combined treatment. As for the genotoxicity assessment, different treatments were compared with corresponding controls and we did not observe a noteworthy difference for selected PAHs either alone or in their binary mixture on primary DNA damage, as evaluated by the alkaline comet assay under our experimental conditions. Given the presence of various PAHs in the air, our future research will focus on more complex mixtures of these compounds and incorporate additional biomarkers of genomic instability to explore potential additive or synergistic effects. Our preliminary results underscore the significance of further toxicological screening of PAHs, especially at low environmentally relevant concentrations, to avoid any possible adverse effects on the environment and human health.

In vitro effect of airborne PAHs and metal mixture on viability and DNA damage in human peripheral blood cells

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Abstract

Exposure to outdoor air pollution, particularly in urban areas, is associated with severe health consequences due to elevated pollutant concentrations. Increased emissions of polycyclic aromatic hydrocarbons (PAHs) and toxic metals, driven by both human activities and natural sources, further worsen this issue. PAHs and toxic metals are known for their carcinogenic and mutagenic properties, primarily due to their ability to interact with DNA. Therefore, here we aimed to investigate the potential cytogenotoxic effect of exposure to a mixture of selected PAHs and metals based on outdoor air pollution measurements obtained for the winter period of the year 2021 in Zagreb (Croatia) on DNA integrity in human peripheral blood cells to mimic real-life scenario exposure under *in vitro* conditions. Blood cells were exposed to a range of concentrations (0.5 – 50 m^3/mL) over 4 and 24-hour treatments. Based on our results, we did not observe the cytotoxic effect of PAHs and metals mixture, however, we did find an increase in DNA damage as measured by the comet assay at the highest concentration tested (50 m^3/mL) at both time intervals, with the 24-hour treatment showing a more pronounced effect. The micronucleus assay results demonstrated an effect on genome stability, indicating different chromosomal and cell lesions. Based on these results, future research will focus on investigating effects in other target cell lines, and three-dimensional cell models to better understand the impact of these compounds, on the cell and chromosomal levels while developing statistical models aimed at identifying potential predictors of genome damage. These preliminary results highlight the importance of further toxicological screening of airborne PAHs and toxic metals either alone or in their complex mixtures, particularly at low environmentally relevant concentrations, to elucidate their mechanisms of action at the cell and molecular level.

The effect of an 8-hour exposure to high temperature and humidity on thermophysiology, thermal perception and energy & substrate metabolism

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Abstract

With global warming progressing, average outdoor temperatures experienced during spring and summer are rising along with fluctuations in absolute air humidity levels. These effects are influencing indoor environments, especially when limited mitigations are employed, like the use of fans, dehumidifiers, or air conditioners. Previous research shows that thermal discomfort and humidity sensitivity increases with higher humidity levels, particularly when ambient temperature exceeds 30ºC (Jing et al., 2013). Many studies have assessed several physiological measures and cognitive performance in various heat and humidity combinations. Those studies mostly assessed shorter periods of time (<2 hours) (Fang, Clausen & Fanger, 1998; Jing et al., 2013; Kleber & Wagner, 2018) or studied repeated exposures (>5 days) (Du et al, 2018). However, little research has been established about the effect of passive exposure to higher temperature and humidity combinations during sedentary activities over the course of 8 hours – the typical duration of an office day. In addition, limited research has been done investigating different levels of humidity exposure among individuals from more temperament climates zones. Therefore, in this study, we assessed the effect of humid vs. dry heat on thermophysiological parameters (such as core and skin temperature, total and local sweat rates), energy metabolism, cognitive abilities and thermal and humidity perception over the course of 8 hours in healthy young adults. Healthy men (n=9) and women (n=13) aged 20-39 y, completed 4 test days over non-consecutive days in a randomised, cross-over design. Participants stayed in a climate-controlled room calorimeter for 8-hours under the following conditions: 25˚C & 30%RH, 25˚C & 70%RH, 32˚C & 30%RH as well as 32˚C & 70%RH. The study is still ongoing at the time of abstract submission and is expected to be completed at the end of May 2024. The full data analysis and results will be presented during the conference.

Comparative Evaluation of Machine Learning Models for Indoor Particulate Matter Concentration Analysis

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Abstract

Indoor air quality is a critical aspect of human health with particulate matter (PM) concentrations being one of the key indicators. Since people spend most of their time indoors, sources of indoor air pollutants such as heating, cooking and smoking are expected to greatly affect indoor air quality and consequently our health. As part of the EDIAQI (Evidence Driven Indoor Air Quality Improvement) project, a pilot study of air quality in households is being conducted in Zagreb (Croatia) where concentrations of particulate matter with an aerodynamic diameter of less than 1 µm (PM_1) are determined. This study presents a comparison of various machine learning models for analysing PM concentrations in households. Our aim is to evaluate the performance of multiple models, including decision trees, random forests (RF), support vector machines (SVM), and extreme gradient boosting (XGBoost).
Our study investigates the ability of each model to capture complex relationships between indoor PM concentrations and a range of influencing factors, such as potential indoor sources, outdoor PM concentrations as well as proximity to traffic as an external source. Evaluation metrics such as mean squared error, mean absolute error, and R-squared were used to assess the models' accuracy, and generalization capabilities. Considering the particularity of the data set, first results on incomplete data have shown that decision tree and random forest models are affected by variables that describe potential sources.
This research may contribute to advancing the understanding of machine learning applications in indoor environmental science and underscores the importance of tailored modelling approaches for diverse indoor settings. All results are part of preliminary testing, and further research will be conducted through the EDIAQI project.

Volatile Organic Compounds in the Air of Zagreb Households, Croatia – Preliminary Results

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Abstract

Today's way of life has led to increased exposure to volatile organic compounds (VOC) in indoor air and therefore the need to investigate their levels and assess impacts on human health. Among VOC, BTEX (benzene, toluene, ethylbenzene, and isomers xylenes) have a significant place in the assessment of indoor air quality. One of the primary sources of BTEX outdoors is traffic, which directly affects indoor air quality. Cigarettes, gasoline, solvents, adhesive removers, paints, aerosols, pest control, degreasers, and spray lubricants are also important sources of BTEX in indoor air. The WHO has classified only benzene as a carcinogenic compound due to its high toxicity, while toluene, ethylbenzene, and xylene isomers are still under investigation for the same properties. Since the EU still lacks legislation on indoor air quality, the overall goal of the recently launched EDIAQI project is to provide guidelines for interventions to improve it.

This work presents the results of preliminary BTEX measurements carried out in the air of ten different households in Zagreb (Croatia) during winter months. The samples were collected on multi-bed tubes by a pump (Markes International) with a flow rate of 0.2 L/min for 6 hours. Samples were analysed by thermal desorption coupled with gas chromatography and mass spectrometry (TD-GC/MS). The results show the highest mass concentrations of toluene, which could not be precisely quantified because the MS detector was saturated. In the case of detector saturation, the ion (m/z = 92) shows a clear flat region close to the apex point. For further improvement, to avoid saturation of the MS detector, it is necessary to reduce the air volume by optimizing the sampling time. The mean mass concentrations of other pollutants were successfully determined in the following order: benzene (3.09 $\mu g/m^3$), sum of *p*- and *m*-xylenes (2.01 $\mu g/m^3$), ethylbenzene (1.97 $\mu g/m^3$), and *o*-xylene (1.79 $\mu g/m^3$).

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Methodology for Analyzing Comfort and CO_2 Levels in the Seville Metro

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Abstract

This study is part of the European EDIAQI (Evidence Driven Indoor Air Quality Improvement) project, which monitors environmental conditions across various buildings in Europe. As part of this initiative, the Seville Metro was selected for a detailed case study, showcasing its strong commitment to passenger well-being and collaboration in advancing indoor comfort and air quality research. Indoor environmental quality, including temperature, relative humidity, and CO_2 concentration, significantly impacts passenger comfort and overall health. Ensuring a comfortable and healthy environment in public transportation systems is essential due to the substantial time people spend in these spaces. Poor indoor air quality can lead to discomfort, reduced productivity, and potential health risks, including respiratory problems and increased susceptibility to airborne diseases.

Environmental monitoring was conducted using portable, high-precision instruments calibrated prior to each session to measure temperature (ºC), relative humidity (%), and CO_2 concentrations (ppm). Measurements were carried out inside metro cars during its circulation along the 18-km Line to ensure representative data collection. Monitoring took place during peak hours (8:00 am – 3:00 pm) over seven consecutive days in three seasons—winter, spring, and summer—to capture both daily and seasonal variations. Data were logged at 1-minute intervals, providing high-resolution results. Statistical analysis identified trends and correlations between environmental parameters, with comparisons made against air quality standards for public transport and buildings. External factors, such as passenger density, ventilation operation, and ambient conditions at above-ground stations, were also considered.

Air quality levels in the Seville Metro system were consistently below the limits required for public transport and, in most cases, below the values established for buildings. Seasonal variations were observed, particularly in CO_2 concentrations during peak travel hours.

In conclusion, the active collaboration of the Seville Metro in the EDIAQI project highlights its dedication to passenger comfort and well-being. By supporting this research, the Seville Metro demonstrates a proactive approach to improving indoor environmental quality and ensuring healthier, more comfortable spaces for its users. This commitment sets an excellent example for public transport systems aiming to enhance user experience and health.

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Impact of overheated bedroom conditions on sleep thermal comfort and sleep quality based on an experimental study

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Abstract

This study investigates the effects of overheated bedroom conditions on measured sleep quality, subjective sleep experience, and sleep thermal comfort, specifically testing the new overheating threshold of 29°C proposed for UK bedrooms that places an upper limit on the mean night-time bedroom temperature. 22 participants (11 females, 11 males) in the age range of 25-50 years with no sleep disorders were monitored over two periods: a baseline period of 5 nights when the participants slept in their own bedrooms under typical summertime temperatures in English bedrooms, and a period of 3 nights in a thermally controlled overheated bedroom in which the temperature was maintained at 30°C ±0.5°C. Objective sleep metrics, such as Total Sleep Time (TST), Time in Bed (TIB), Sleep Efficiency (SE), Wake%, Sleep Onset Latency (SOL), and Fragmentation Index (FI) were measured using wrist actigraphy, alongside self-reported sleep quality, freshness, and sleep thermal comfort. Baseline sleep quality and sleep thermal comfort metrics were compared with those experienced under overheated condition. While TIB, SE, and SOL remained relatively stable, TST showed a significant reduction of 24 minutes under overheated conditions, indicating a meaningful decline in sleep duration. Participants reported significantly lower self-rated sleep quality ($p<0.001$) and freshness ($p<0.001$) in overheated conditions, highlighting the value of self-reported sleep quality monitoring. The analysis of thermal comfort votes confirmed significant discomfort in overheated conditions ($p=0.002$) with participants reporting a significant preference for cooler temperatures ($p=0.008$). Our results show that a bedroom temperature of higher than 29°C degrade both sleep quality and sleep thermal comfort, supporting the newly proposed upper threshold for temperature in UK bedrooms. Further research on mitigation strategies, such as cooling technologies and personalised interventions, is needed to reduce thermal stress and protect sleep health.

Review of empirical studies on health and comfort in relation to building characteristics during summer in Europe

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Abstract

Changing outdoor conditions, i.e. higher outdoor temperatures, higher occurrence of heatwaves and outdoor air pollution, increase the risk of overheating and accumulation of air pollution in dwellings. In Europe, the rise of the outdoor air temperature is higher than the global average. Previous studies showed that increased indoor temperatures and air pollution affect occupants' health, resulting in cardio-vascular diseases, respiratory, eyes and skin complaints. Measures to reduce energy consumption in renovated or newly built dwellings can affect the occupants' health negatively and further increase health risks during extreme weather events. The objective of this study is to systematically review consequences of outdoor conditions, building characteristics, and technology on the indoor environment and occupants' health in dwellings in European countries during summer. This review focuses on empirical studies, as these enable to capture real world interactions of occupants and buildings in relation to outdoor conditions. Varying outdoor conditions, building characteristics, and occupant-related aspects throughout different European climate zones are discussed. The main finding is that overheating occurs yet in normal summers in warm, temperate and northern European countries, while large variation is related to different occupants' adaptive behaviour and building characteristics. Due to the ongoing climate change, changing adaptive behaviour, and evolving energy efficient technologies, study of adaptability of dwellings to these changes is required to contribute to energy efficient, health supporting dwellings.

Improving Indoor Air Quality in Higher Educational Institutions: An Evidence-Based Approach

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Abstract

Managing indoor air quality (IAQ) in university classrooms has become a pressing concern, given its direct impact on health, cognitive function, and overall productivity. This study uses an evidence-based approach to explore the relationship between indoor air quality (IAQ) and the occupant perception of indoor environment quality (IEQ) – specifically studying how the long, medium and short-term IAQ conditions correlate to the perceptions reported by occupants. The research employs a mixed-methods approach, combining quantitative data from air quality sensors and qualitative feedback from occupants. The study begins with baseline IAQ assessments in two classroom typologies at the American University in Cairo, measuring carbon dioxide levels, particulate matter (PM2.5), volatile organic compounds (tVOCs), temperature, and relative humidity. Surveys with students provide insights into perceived air and environmental quality conditions in these spaces. The findings of the correlation analysis at the different timeframes underscore both short-term and long-term IAQ conditions that influence occupant perceptions of indoor environmental quality (IEQ). Temperature appeared to be a primary factor influencing immediate comfort. Carbon dioxide (CO_2) and total volatile organic compounds (tVOC) are more significant in medium-term and long-term perception. The study highlights the dynamic nature of occupant perceptions and underscores the need for new and more comprehensive approaches to managing IAQ in educational buildings. The findings highlight the need for proactive IAQ management in higher education facilities, advocating for policies prioritizing health and well-being. Higher educational facilities can significantly improve the indoor environment by analyzing current IAQ conditions and their links to occupants' perceptions, identifying the critical IAQ parameters and cultural biases, and implementing targeted interventions.

The Cool Down Coach – An occupant oriented behavioural coach for effective ventilative cooling and solar shading

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Abstract

Due to climate change Dutch homes are increasingly suffering from overheating, which can lead to discomfort and sleeping problems that are detrimental for resident's health and wellbeing. Overheating can also lead to increased use of energy consuming air-conditioning devices. In mild oceanic climates overheating can largely be prevented through passive measures like solar shading and ventilative cooling. Previous research has shown, however, that residents do not always operate windows and shading devices effectively, sometimes opening windows at midday allowing warm air to enter or keeping windows closed at night preventing the home from cooling down with cool outside air.
This paper presents the results of a study aimed at the development and testing of a Cool Down Coach (CDC). The CDC is an internet-of-things enabled device that supports residents in keeping their home cool through effective use of ventilative cooling and solar shading. The CDC uses locally measured indoor and ambient temperatures, weather forecasts, and a user-interface, shown on a display and mobile phone. A prototype of the CDC was tested in seven homes in the Netherlands and from six of them, data and user feedback were obtained. Most residents reported that they found the CDC useful and accurate, making them more aware of their behaviour. The measurements provided useful insights to the tenants about their actual behaviour. However, monitoring showed that the advice from the CDC was not always followed. Reported reasons include fear of raining in and nuisance of insects (during daytime) and fear of burglary, nuisance of insects and outside noise (mostly during nighttime). It appeared that changing established behaviours remains a challenge, even with aid of the CDC. In conclusion, the CDC is a valuable tool for stimulating optimal cooling behaviour and providing insights, but it cannot, by itself, fully resolve overheating issues.

Data-driven approach to construct typical window behavior profiles during summer and heat waves: Insights from 76 naturally ventilated French buildings

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Abstract

Climate change is causing increasingly intense and frequent heat waves. During these extreme periods, occupants play a crucial role in the overheating of their homes and, consequently, their thermal comfort. To anticipate the impact of heat waves on buildings during the design phase, it is essential to develop occupant behavior profiles that accurately reflect real adaptation behaviors to summer and heat wave. These behaviors may sometimes be inconsistent with optimal thermal regulation of the indoor environment, due to influences such as personal beliefs, habits, noise or other factors. Based on data from 76 naturally ventilated dwellings in three French regions during the summer of 2023, this study uses a k-means clustering approach on daily window opening profiles to construct 15 typical daily profiles. The results reveal significant diversity in occupant behaviors. It is possible to identify four groups of typical daily profiles: one group with mainly closed windows, another with mainly open windows, a group with windows open during the day, and a group with windows open at night. This study shows that many occupants do not adopt night-time ventilation behavior to prevent overheating. To explain the 15 daily behavior profiles and identify which types of occupants adopt these behaviors, and under what conditions they do so, a correlation analysis using the Pearson coefficient is conducted between explanatory variables (outdoor conditions, buildings and occupants' characteristics) and the typical daily window profile. The analysis suggests that outdoor temperature is one of the most influential parameters of behavior, and that region of residence, smoking habits, noise levels, and room type are also very important factors. The creation of these typical occupant behavior profiles regarding window usage will enable more realistic scenarios of occupant behavior during summer and better predictions of home overheating.

Enhancing Health, Energy Efficiency, and Safety in Childcare Centers through Automated Climate Control Systems: A Case Study in a Nursery in Seville

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Abstract

Poor hygrothermal conditions and inadequate indoor air quality have been shown to aggravate various health conditions as well as temporarily reduce cognitive performance and increase susceptibility to airborne diseases, such as COVID-19, primarily due to insufficient ventilation. The study of thermal comfort, air quality, and the risk of airborne pathogen transmission is essential for promoting wellness, health, and safety in indoor environments. Childcare centers demand special consideration since younger children, with their immature immune systems, are especially vulnerable to respiratory conditions and other diseases. Currently, a limited number of these centers have analyzed the air quality in their classrooms.

This study focuses on monitoring a daycare center in Seville, Spain, to assess indoor air quality and associated health risks. The data revealed that well-intentioned caretakers often prioritize maintaining comfortable hygrothermal conditions over adequate air quality, typically due to unfavorable outdoor conditions and the absence of CO_2 monitoring devices. As a result, younger infants are frequently exposed to high rates of airborne pathogen transmission and CO_2 concentrations that significantly exceed acceptable levels for extended periods. Additionally, the lack of automation in the classrooms' climate control systems led to inefficient use of air conditioning, causing a substantial increase in energy consumption required to maintain occupant comfort.

The findings suggest that automating the climate control and mechanical ventilation systems by linking them to devices that monitor temperature, humidity, and CO_2 levels in the classrooms could be beneficial. Such automation would not only improve air quality but also optimize energy use, thereby enhancing the overall well-being and safety of the occupants. This study underscores the importance of integrating environmental monitoring and automated systems in childcare settings to ensure both health and energy efficiency.

The Butterfly Effect: Impact of Building Design and Occupant Behavior on Residential Energy Consumption

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Abstract

The demand for energy-efficient buildings necessitates an in-depth understanding of the factors affecting energy consumption at building and cluster levels. This study investigates the interplay between building parameters and the probability of occupants' air conditioning and heating (AC/H) use based on indoor air temperature. By integrating energy simulation models with on-site measurements, the paper comprehensively analyzes these variables' impact on energy consumption. This analysis is based on data from on-site measurements of four residential units within a cluster: two conventional houses and two enhanced dwellings optimized for airtightness and higher heat-resisting materials. The study uses a probabilistic model to assess how occupants respond to varying temperatures by adjusting their AC/H usage patterns. This was modeled and simulated across different scenarios, reflecting varying occupants' heat tolerance levels. Using probability curves from previous studies tested for sensitivity, we simulated and aggregated energy consumption at building and cluster levels for the typical building prototypes and prototypes with enhanced envelopes. For situations with low heat tolerance, the energy simulations revealed that the improved buildings could reduce energy consumption by nearly 50% at the building level and 47% at the cluster level. This study shows the importance of a complete building design and energy management approach. The findings support policies focusing on air tightness, material selection, and understanding occupant behavior, illustrating that even minor adjustments can significantly impact. The results emphasize the importance of integrated design and occupant behavior in urban energy planning.

Natural light and physiological response under extreme conditions

Chairs: Ignacio Acosta / Pedro Bustamante

Investigating the Relationship Between Subjective Assessments and Spatial Daylight Autonomy in Offices

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Abstract

Available daylight provision metrics are based on climatic data to assess temporal and spatial daylight availability indoors. The current targets used to benchmark a room's daylight performance are related to the visual perception of office workers. This study aimed to examine the relationship of illuminance and spatial Daylight Autonomy (sDA) with occupant's satisfaction using different methods to collect their subjective perception. We collected data on thermal and luminous environments, such as vertical and horizontal illuminance through a field study at the Technical University of Denmark (DTU) during the spring of 2024. Nine volunteers answered questionnaires to assess their preference and satisfaction with the amount of daylight on the desk, and their satisfaction with the perceived daylit area in the room. The measurements were conducted on separate days, under two different conditions: (1) blind/curtains open; (2) blinds/curtains as the participants typically use and prefer. Under both scenarios, the electric light was always off. The results indicated that occupant satisfaction correlated significantly with illuminance levels and perceived daylit areas under non-glaring conditions, with horizontal illuminance below 1510 lux and vertical illuminance below 1650 lux. However, in the presence of glare, satisfaction showed a stronger correlation with the proportion of the daylit area rather than illuminance. If integrated with other studies with a similar approach, the results can be used to optimize daylighting in indoor environments for well-being by providing insights for more occupant-centric standards in daylighting.

Improving well-being and health by means of multispectral lighting in the build environment: The C-Light ecosystem

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Abstract

The latest advances in LED technology and biomedicine have encouraged the development of multi-channel luminaires, which allow the adaptation of the light spectral distribution to the requirements of human chronobiological markers. However, there is a lack of biochemical tests that guide a suitable lighting design according to the requirements of health and well-being.

Moreover, numerous studies have confirmed that ultraviolet light (UV) allows the inactivation of bacteria when it emits with a spectral peak of 380 nm wavelength and promotes the breakdown of the DNA and RNA chains of viruses and bacteria in emission ranges of 220 and 270 nm. Present control technology allows a safe use of UV lighting in healthcare facilities. Current studies in this research line show promising results in the neutralization of viruses, including SARS-CoV-2, as well as the elimination of bacteria responsible for nosocomial diseases.

Given this context, the research projects of C-Light ecosystem (CHRONOlight and NEUROlight among others) aim to develop a biodynamic wide spectrum lighting system, that contributes to the recovery and health improvement of hospital patients and their caregivers. To achieve this objective, the lighting system render a spectral distribution according to the suitable regulation of chronobiological markers, based on biochemical measurements of cortisol and melatonin, while contributing to the elimination or neutralization of pathogens in healthcare facilities through the emission of UV light, avoiding the proliferation of nosocomial diseases and viruses.

The results indicate that biodynamic lighting fixtures produce statistically significant improvements in chronobiological markers compared to conventional lighting systems. Additionally, the inclusion of UV channels effectively reduces bacterial colony proliferation within the observed environments of hospital rooms and Intensive Care Units at Hospital Virgen del Rocío in Seville.

Exploring the impact of daylight quality on human responses under warm temperature: a living lab study

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Abstract

Light quality plays a crucial role in shaping our well-being and work performance. In this study, we aimed to explore whether daylight quality affected people's perception of thermal and visual comfort, concentration, and well-being. Our controlled experiments took place in a living lab, simulating a typical office environment. A diverse group of 24 healthy adults (12 females) with at least one year of adaptation to Danish weather participated in six experimental sessions during the fall season. Participants experienced one hour of exposure to 29°C. Three types of window glazing were tested: low iron, low emissivity, and tinted. Participants were exposed to two different urban views: a courtyard and a parking lot. Participants provided subjective assessments of the indoor environment and self-reported performance, concentration, and stress four times during each session. Concentration and task engagement were measured twice per session. Skin temperature at seven body parts and heart rate variability were continuously monitored. Thermal and lighting parameters were recorded every minute. When exposed to tinted glazing, participants exhibited lower concentration performance, reduced thoroughness, and decreased task engagement. Thermal comfort was poor for most participants, whereas thermal acceptability was higher with low-e and tinted glazing. More participants were comfortable with the daylight levels at the desk when exposed to low-e and low iron glazing compared to tinted glazing. Our findings underscore the importance of considering daylight quality in indoor environments. Architects, designers, and facility managers should consider the impact of glazing choices on occupants' cognitive functioning and well-being. Further research is warranted to explore these effects across larger populations and diverse contexts.

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The Fragmented Light Shelf (FLS) as a System that improve natural lighting and decrease the energy consumption.

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Abstract

The light shelf is an architectural element that reflects natural light into the interior of a building, it is a passive static system, while the incident light is a dynamic source, which constantly changes in altitude, azimuth, and intensity. Therefore, it is difficult to achieve a perfect daytime lighting system that reflects 100% of the light 100% of the time. However, it has been shown in previous work that incorporating light shelves into a project can be a great way to improve natural lighting and decrease the energy consumption.

Light shelves are primarily used in climates where there is an abundance of sunlight throughout the year. They are especially useful in climates where direct sunlight can be intense and potentially cause glare or overheating in indoor spaces. In colder climates, light shelves can help maximize natural light in interior spaces, which can help reduce the need for artificial lighting and heating. Though, the design must consider the direction and intensity of sunlight and the need for shading during different times of the year. In hot climates, light shelves can provide shade and reduce solar heat gain, while reflecting natural light into the building.

Although FLS in Madrid has already been studied previously, in a PhD work, demonstrating that it works correctly, improving natural lighting (in winter) and providing solar protection (in summer). This article aims to address the implementation of light shelves in the three predominant climate typologies of Spain, according to Köppen, Oviedo Cfb = Temperate oceanic climate; Madrid BSk = Cold semi-arid climate; and Malaga Csa = Hot-summer Mediterranean climate. By using Revit 2022 as software to build the models, VELUX Daylight Visualizer software to analyse daylighting and Insight plugin to estimate the Energy Use Intensity.

A simulation study on the impact of window filters on the non-image forming effects of light, visual comfort, and thermal sensation

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Abstract

Visual, thermal and spectral properties of translucent facades can have a significant impact in occupant's visual comfort and thermal sensation in near-window zones. Moreover, the use of translucent window filters used to vary the color temperature and intensity of the incident radiation through windows also has impact on the non-image forming (NIF) responses of light. The aim of this investigation is to explore the circadian stimulation, visual comfort and thermal sensation of different window filters on office users in a simulation study. We considered the spectral properties of 10 window filters to conduct daylight and thermal simulations were performed on the LOBSTER model with different window filters to assess the circadian stimulation, visual comfort, and thermal sensation considering both with and without direct sunlight. We used the metric Melanopic Equivalent Daylight Illuminance (MEDI) to evaluate NIF, while Predicted Mean Vote (PMV), and Daylight Glare Probability (DGP) were used to evaluate thermal sensation and visual comfort, respectively. Point-in-time simulations were performed for both equinoxes and solstices during working hours (8:00-16:00). Our results showed that the selection of window filters significantly influences predicted visual comfort, circadian stimulation, and thermal sensation of building occupants, underscoring the importance of performing both, daylight and thermal simulations to ensure healthy and comfortable evaluation of buildings when selecting appropriate window glazing filters.

Influence of daylight transmitted through blue coloured glazings on human response to temperature and glare

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Abstract

Façade properties influence human responses in a multidomain manner and these interactions needs to be accounted for effective façades design, particularly to increase resilience to extreme heat. From existing research, it remains unclear whether the glazing colour properties can influence occupant thermal sensation, preferences, and acceptance, or whether higher temperatures affect glare sensation or view perception. This study investigates the combined influence of tinted glazing in façades through a preliminary experimental campaign with human participants exposed to varying glazing hues (neutral and blue) and indoor air temperatures. While previous research has examined the impact of coloured daylight on thermal and glare sensation under thermal conditions close to neutrality, this paper compares occupant responses at neutral and warm thermal conditions by performing repeated measurements.

An experiment was conducted to measure potential differences in human thermal sensation, acceptance, preference, and glare sensation under two thermal conditions (operative temperatures of 25°C and 30°C) and two daylight colours (neutral and blue). Thirty-nine participants were exposed to different combinations of temperature and glazing colour in a randomized order. Data were collected using questionnaires and thermal physiological sensors to capture human responses to these varying conditions. In terms of visual perception, the results demonstrate a distinction between the two visual scenarios, particularly regarding obstruction and glare at a neutral temperature. At the level of thermal sensation, the impact of blue-tinted glazing is not statistically significant with this number of participants. However, a slight difference is observed between the two scenarios at both temperature levels.

CATE 2024

Evaluating daylight, thermal comfort and operational energy performance of the Living Places: a comparative study between Copenhagen and Kyiv

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Abstract

The Energy Performance of Building Directive's (EPBD) guidelines to reach net zero emissions by 2030 for new constructions encourage energy efficiency amidst the ever-growing global building stocks. A prefabricated modular housing concept that can be optimised according to the climatic conditions that focus on sustainability and energy efficiency could address such goal while achieving high indoor comfort conditions for humans. This work is a comparative study of one such concept, The Living Places Copenhagen. The work studies its adaptability in the different climatic context of Kyiv, promoting visual and thermal comfort and calculating the environmental impact for the operational energy use phase of the building life cycle. The metrics at focus were Spatial Daylighting autonomy (sDA300/50%), annual percentage of adaptive comfort hours and Primary Energy (PE) demand. Parametric simulations were performed to assess the performance of the building aperture to identify the optimal cases in Kyiv and compare them with the base case using the Active House specifications. The study showed that larger windows increase the daylight availability but can cause discomfort due to heat gain and loss, affecting energy demand. Higher glazing transmittance (Tvis) and solar heat gain coefficient (SHGC) can improve daylight and energy use but also lead to discomfort. Buildings with windows on multiple facades benefit from multidirectional daylight. The ideal window setup depends on the desired balance between daylight, thermal comfort, and energy demand. The optimal cases presented in this study achieve $sDA_{300/50\%} > 70$ % of the occupied floor area, adaptive thermal comfort hours > 95 % of the occupied hours and an average annual energy demand of 32.87 kWh/m²/y with a corresponding carbon footprint of 11.22 $kgCO_2$-eq./m²/y for operational energy use phase.

Optimizing Window Design for Energy Efficiency, Natural Light, and Occupant Well-being in Residential Buildings in Mediterranean Climates: A Case Study in Seville, Spain

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Abstract

This study examines window dimensioning and positioning in bedrooms of residential buildings in a Mediterranean climate, particularly in Seville, Spain. The research is motivated by the need to balance energy efficiency and natural light access, which are critical factors in both occupant well-being, health and energy consumption. The design variables considered include window size, proportion, position, and orientation. These factors are known to influence the amount of natural light entering a room, the efficiency of building insulation, and the physiological health benefits derived from exposure to natural daylight.

The methodology applied involves simulations using digital modelling and various performance indicators, such as energy demand, Daylight Autonomy, and Circadian Stimulus Autonomy. A case study was conducted in a standard bedroom in a multi-family residential building in Seville. Different window configurations were modelled to evaluate their performance under diverse conditions, including variations in window size, position (centred or off-centre), and orientation (north or south). Energy performance was calculated through software tools like *CYPETHERM HE Plus*, while lighting metrics were assessed using *Climate Studio*.

The findings demonstrate that larger, well-positioned windows significantly improve natural light penetration, enhancing visual comfort and reducing the need for electric lighting. Moreover, south-facing windows are more effective in energy savings during winter but require solar shading in summer to prevent overheating. Optimizing window design, especially in terms of balancing size, orientation, and energy efficiency, is crucial for improving occupant well-being and reducing energy consumption in Mediterranean climates.

The study concludes that an integrated design approach, which considers both aesthetic and technical factors, is essential for achieving sustainable and healthy residential environments in regions with similar climatic conditions.

Colourful Daylight: Evaluating the spectral transmittance of daylight through window films

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Abstract

In recent years, window films have emerged as a popular solution for managing solar heat gains across diverse climatic conditions, ranging from extreme to moderate weather. While these films effectively reduce unwanted heat gains, they often compromise daylight availability and modify the colour of natural light. This study quantifies the spectral irradiance of window films, serving as a basis for energy, daylight, and colour assessment. We looked at high and low transmittance levels for correspondingly moderate and extreme weather conditions.

A comprehensive analysis was conducted on 14 different window films, with visual transmittance from approximately 6% to 86%. The spectral power distribution (SPD) of each film was meticulously measured using a spectrometer. The collected data provide a holistic visual and non-visual evaluation of the films' performance.

The results reveal significant insights into the trade-offs between visual transmittance and correlated colour temperature (CCT). High transmittance films allow more natural light penetration but can lead to unwanted heat gains. Low transmittance films effectively block solar heat but often at the cost of reduced daylight and altered colour rendering. The study discusses the advantages and disadvantages of the evaluated films.

Finally, this research highlights the need for a balanced approach when choosing window films, considering daylight quality. The findings serve as a valuable resource for architects, building engineers, and environmental designers seeking to optimise building performance with visual and non-visual aspects of daylight through informed decisions on spectral evaluation of windows films.

Optimizing Electric and Natural Lighting for Health, Well-being, and Productivity in 24-Hour Workspaces: A Case Study in Seville, Spain

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Abstract

This paper examines the design and regulation of electric lighting systems (luminous flux and light spectrum) and access to natural light in 24-hour workspaces in Mediterranean climates. Using Seville, Spain, as a case study, the research addresses the impact of lighting on health, well-being, circadian rhythm regulation, and work performance. Poor lighting conditions are linked to sleep disruption, depression, and decreased productivity, especially in climates with extreme heat and abundant natural light.

The methodology involves in-situ lighting measurements and user satisfaction surveys in two 24-hour study rooms at the University of Seville. The study evaluates both electric and natural lighting, focusing on their interaction and the effect of colorimetry, illuminance levels, and chromatic perception on occupant comfort. Measurements of luminous flux, spectral composition, and uniformity were complemented by user surveys to assess visual comfort and preferences.

Results indicate that a combination of electric and natural light optimizes visual comfort, with cold light (above 5000 K) enhancing alertness and reducing eye strain during nighttime hours. Additionally, windows should be oriented to maximize daylight without causing excessive glare, and electric lighting should allow for spectrum adjustments to maintain circadian rhythm alignment.

In conclusion, the study provides guidelines for lighting design in 24-hour workspaces, recommending adjustable electric lighting systems with a focus on luminous intensity and spectral quality, alongside optimal natural light access. These measures can improve well-being and productivity in regions with extreme climates.

Design Intervention in Buildings for thermal comfort

Chair: Holly Samuelson

Impact of Climate Change and Adaptive Comfort Strategies in Social Housing: A Study in Quito and Esmeraldas

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Abstract

Studying thermal comfort in extreme climates, such as the temperate oceanic climate (Cfb, climate according to Köppen-Geiger) of Quito (Ecuador), characterised by cool temperatures and significant rainfall, and the tropical monsoon climate (Aw, climate according to Köppen-Geiger) of Esmeraldas (Ecuador), marked by high humidity and intense heat, is essential for ensuring sustainable and habitable architectural designs that adapt to diverse environmental conditions.

This study focuses on evaluating the thermal performance of a social housing prototype in two locations with highly contrasting climates. The analysis specifically examines the response of the building in both cities (Quito & Esmeraldas), focusing on the differences between the ground floor and the upper floor of the prototype, due to the varying results obtained depending on the building's envelope.

By using the DesignBuilder software, simulations were conducted to assess both current climatic conditions and future projections for 2050, under different Representative Concentration Pathways (RCP2.5, RCP4.5, and RCP8.5). The results highlight how the housing prototype responds to the distinct climate challenges in each location and across the two floors of the building.

The implementation of adaptive comfort models and adaptive heating and cooling set points led to significant energy savings, with reductions of 55% in Quito and 98% in Esmeraldas. In terms of climate change impacts, Quito showed favorable outcomes, with a nearly 30% decrease in heating demand across the housing block. Conversely, results in Esmeraldas were mixed; the ground floor unit experienced reduced heating consumption, while the upper floor unit showed increased cooling demand.

Overall, an average energy savings of 75% was achieved when adaptive strategies were employed across all scenarios. Thus, this research underscores the importance of context-specific adaptive comfort measures in optimizing energy efficiency in social housing, contributing to sustainable development goals and climate resilience in diverse urban environments.

Thermal Massing As A Retrofit Tool For Better Comfort In Mass Housing Constructions In The Context Of Urban Slums In Dhaka

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Abstract

This paper aims to develop ways to improve the living conditions of multistory informal mass housing constructions in Dhaka, the capital city of Bangladesh. Lack of livelihood opportunities throughout the year, climate change induced migration compels rural people of Bangladesh to migrate to urban areas. Since Dhaka offers various job opportunities, the city witnesses an influx of over two thousand migrants daily. These economically disadvantaged individuals are constrained to inhabit the informal settlements that dot the urban landscape of Dhaka. In the process, urban slums have become an integral part of the city morphology. Since there is no legal foundation of such informal settlements, the houses are built with materials like corrugated iron sheets, prefabricated concrete posts, bamboo or wooden planks etc., so that they can be easily dismantled in an event of eviction. Moreover, these shanty structures are mostly multi-storied to accommodate the huge influx of migrants. Altogether, these informal housing structures lack livability qualities of all kinds. Among them, thermal comfort is highly compromised. Within this design research, typical informal housing constructions in an urban slum in Dhaka will be investigated in terms of their thermal performance within the prevailing articulation of the interior spaces. Building upon precedent studies, within this paper architectural passive design strategies are proposed in order to enhance both the living quality and energetical performance of these informal dwellings. Special emphasis is placed on incorporating additional thermal mass into existing structures to mitigate temperature fluctuations and curb interior overheating during the daily heat peaks of the sweltering summer months. The findings of this design research show viable construction proposals which intend to guide the retrofitting process of such informal urban slum structures towards a more hospitable thermal environment conducive to improved living standards.

Exploring the Synergy of Thermal Mass and Air Cooling Systems in Multistorey Buildings: A Comparative Case Study Across Diverse Climate Extremes

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Abstract

The interplay between thermal massing and air cooling systems represents a critical nexus in the pursuit of sustainable and efficient building design. This paper compares and explores the potential of these strategies across different climatic regions, aiming to assess their cooling efficacy, limitations in specific climatic extremes, and optimal utilization. In temperate climates characterized by moderate temperature fluctuations, the integration of thermal massing—especially in combination with nocturnal ventilation—proves advantageous in stabilizing indoor temperatures during hot summer days. Buildings constructed with materials possessing high thermal mass, such as concrete or brick, demonstrate the ability to absorb and store heat during the day, gradually releasing it during cooler nights, particularly when spaces are well-ventilated at night. When paired with passive cooling techniques like natural ventilation, thermal massing significantly reduces reliance on mechanical cooling systems, promoting energy efficiency and thermal comfort. In contrast, in arid climates typified by scorching temperatures, the efficacy of thermal massing depends on nuanced ventilation strategies. While thermal massing can help moderate diurnal temperature swings, excessive heat accumulation during the day poses challenges without adequate ventilation, nocturnal cooling, or active cooling mechanisms. Consequently, the integration of air cooling systems becomes essential to address the inherent limitations of thermal massing. In tropical climates with high humidity and consistent warmth, the interaction between thermal massing and air cooling systems requires careful calibration. Here, the focus shifts toward improving interior comfort by managing moisture levels and preventing the buildup of condensation within building envelopes. By examining buildings typical of their respective locations, this paper elucidates the nuanced interplay between thermal massing and air cooling systems. By delineating their synergies and trade-offs, the analysis provides insights for developing context-specific strategies for sustainable building design and climate resilience.

Enhancing Summer Thermal Comfort in Andalusian Social Housing: A Comprehensive Approach to Climate Change Adaptation

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Abstract

Climate change is a pressing global issue, with cities and buildings contributing significantly to CO_2 emissions. Rising temperatures and frequent heat waves increase heat stress, particularly in the Mediterranean. In Andalusia, the southernmost region of Spain, social housing, especially older buildings, suffers from poor environmental performance. This problem is worsened by the detected low energy consumption profile, as residents cannot afford the high cost of electricity for cooling, leading to significant discomfort and thermal stress. Addressing this requires the refurbishment of buildings using passive strategies to improve indoor thermal comfort and habitability, which is in line with current European objectives. This research focusses on the social housing stock built in Córdoba, a city that faces extreme summer conditions. By using energy simulation models and real data from annual monitoring of environmental parameters, the study explores comprehensive improvement strategies like insulation, window replacement, and ventilation control that will be applicable to many buildings in the city. This work delves into the effect of these standard strategies on improving indoor thermal comfort to cope with the high temperatures recorded in summer. The strategies are tested in current and future climate scenarios, so that the study outcomes could also benefit northern regions facing similar temperature increases. Given the severity of prolonged high-temperature periods, the improvements obtained through passive strategies are insufficient, highlighting the need to implement cooling systems based on renewable energy sources.

CATE 2024

Exploring strategies for resilience to overheating in low-energy buildings

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Abstract

The predicted increase in temperatures resulting from climate change is likely to generate an alarming rate of health-related risks for vulnerable groups of people. While there is a growing attention on people protection strategies, governments are mainly promoting the implementation of mitigating measures to reduce energy demand from buildings. In European countries, low-energy buildings are designed with a view of securing winter comfort, hence they incorporate strategies for reducing energy demand for heating via an optimised building fabric that reduces thermal transmittance through insulation and controlled ventilation with heat recovery.

Such energy-efficient strategies, if improperly implemented, can aggravate overheating – this point has been made in the literature, which has evidenced an increased risk of overheating in highly insulated low-energy residential buildings in temperate climates as a result of a combination of inadequate ventilation provision and absence of solar control.

Most recent thermal comfort studies have focused on the human capacity to adapt (up to a certain level) to changing temperatures. Related to this, specific scientific attention has been paid to adaptive measures of comfort. Comfort is a multidimensional system, which includes several sensorial perceptions, such as sight, sound, smell, and memory) as well as other factors affecting such perceptions.

This paper explores the complex relationship between comfort, human behaviour, and low-energy building design in the face of climate change and asks how occupant actions can help mitigate overheating.

Bridging the gap between building science and building practice, this paper presents forefront research on climate change risk and on adaptive means of comfort. The advanced research question was *how human-building interactions can reduce exposure to climate change induced overheating in low-energy buildings*. This objective was specifically tackled by critically reviewing field work studies on comfort and human-building interactions affecting indoor temperatures in low-energy buildings during a warming climate. Overall, the performed research highlights the importance of a multifaceted approach to reducing vulnerability to overheating, considering both building design and human behaviour.

Plywood ceilings reduce heat-health risks in tropical school classrooms

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Abstract

With increasing extreme heat events in the tropics, schools authorities are finding it challenging to provide comfortable and safe learning environments for school children. Despite the dangerous impacts of extreme heat, little is known about classroom temperatures in tropical climates and how they can be reduced. This study measured temperatures in seven school classrooms in Accra, Ghana for 389 days. All classrooms had a metal roof, but one had a plywood ceiling beneath. Extremely high classroom temperatures of up to 39.8°C were recorded in the classrooms without a ceiling, which exceeded outdoor temperatures by up to 5.9°C. The presence of a plywood ceiling under a metal roof reduced the number of overheating hours by half. Roof materials with low thermal transmittance thus protect school classrooms, and the children and staff in them, from the heat of the day. Classrooms with metal roofs could be cost-effectively retrofitted with plywood ceilings to ensure that children in tropical cities have safer, healthier classroom environments that are more conducive to their learning, health and wellbeing.

Redefining comfortable offices in tropical climates: A case study on semi-outdoor workspaces in Singapore

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Abstract

This study explores the viability of semi-outdoor workspaces in Singapore, where traditional offices rely heavily on air-conditioning resulting in high energy consumption. This research focuses on how to establish non-air-conditioned workspace that is acceptable by occupants in the tropics. Conducted at the semi-outdoor workspace, known as the K/Park, this study examines thermal comfort without air-conditioning. Continuous physical measurements of indoor air temperature, globe temperature, humidity, and air speed were taken at one-minute intervals near the workstations within the K/Park. Outdoor weather conditions were also monitored for reference. Subjective surveys on occupant thermal sensation, preference, satisfaction, and reasons for dissatisfaction were examined. Over a two-month period, the ceiling fans were adjusted to 35 %, 50 %, and 70 % of their rated speed to assess the impact on occupant feedback. Conditions with air-conditioning at 26 °C, 27 °C, and 28 °C setpoints had been arranged for performance comparison. Under natural ventilation, a mean indoor temperature of 30.4 °C and relative humidity of 70 % were recorded during working hours, with air movement ranging from 0.15 m/s to 1.83 m/s depending on outdoor wind speed, ceiling fan settings, and sensor heights. Notably, up to 68 % of the K/Park users reported thermal satisfaction, with less than 20 % expressing dissatisfaction, when sufficient air speed was provided from the ceiling fans. Thermal dissatisfaction from different sources generally reduced with higher ceiling fan speed. However, future works are needed to address discomfort with high humidity under natural ventilation. These findings show that natural ventilation and strategic air movement can create comfortable and energy-efficient workspaces in tropical climates, providing a sustainable alternative to air-conditioned offices. These results from a real-life building, rather than a climatic chamber, offer a valuable reference for promoting non-air-conditioned workspaces in the tropics.

Glazed balconies: the poor thermal and energy performance of São Paulo's high-end apartments under current and future climate

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Abstract

Over the past thirty years, heatwave frequency in Brazil has risen from 7 days per year to over 50. Power outages have become increasingly common, partly due to excessive demand for air conditioning. Thus, it is urgent to design buildings adapted to heat extremes, to ensure thermal comfort and energy efficiency. Yet, local architectural trends might be heading in a different direction. Since 2014, after changes in local building codes, large, glazed balconies have become essential in most mid-to-high-end apartments in São Paulo. These balconies serve as a second living room rather than a transitional space between interior and exterior. In tropical climates, such glazed envelopes have widely known consequences, at least for office buildings: intense thermal discomfort and inevitable reliance on air conditioning. However, more research is needed for residential apartments, especially for high-end units. Hence, this exploratory study investigates how glazed balconies have impacted the thermal and energy performance of high-end apartments produced over the last decade in São Paulo. This was conducted by running EnergyPlus simulations of a representative sample apartment, which was modeled based on 220 newly launched plans. Different scenarios were tested for current and future weather files, varying the balcony's glazing, its opening factor, and the separation between the balcony and the living room. Results indicate that keeping the balcony's glazing closed dramatically increases overheating, from 7% to up to 68% of occupied hours, or up to 81% in future climate. HVAC consumption increases by one order of magnitude, almost doubling the apartment's total power intake. Thus, this very popular home design in the city today might be among the worst-performing options, highlighting the importance of reclaiming balconies' role as a space for natural ventilation and shading – an opportunity, in increasingly dense cities, for some contact with the exterior.

CATE 2024

Justifying Findings on Passive Houses Towards UK's Net Zero Target

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Abstract

In pursuit of achieving net-zero carbon emissions by 2050, the United Kingdom faces the critical challenge of transforming its building sector, a significant contributor to greenhouse gas emissions. Central to this effort is the adoption of energy-efficient building standards such as the Passivhaus design. Originating from Germany, Passivhaus integrates principles of superior insulation, airtightness, and mechanical ventilation heat recovery (MVHR) to drastically reduce energy consumption and carbon emissions in residential buildings.

This paper presents a comprehensive review of five case studies on Passivhaus residences in the UK, emphasizing the assessment of total carbon footprint—combining both embodied and operational carbon. The research scrutinizes these homes against traditional builds to discern their efficacy in meeting sustainability targets. Key findings underscore significant reductions in operational energy demands, aligning with existing literature highlighting Passivhaus' ability to achieve up to 90% energy savings compared to conventional buildings.

Moreover, the study addresses a critical research gap by delving into embodied carbon emissions, an area often overlooked in previous discourse but increasingly pivotal in achieving holistic sustainability goals. By employing a detailed comparative analysis, this research reveals nuanced insights into the lifecycle impacts of Passivhaus homes, examining the carbon-intensive phases of construction materials and processes. These insights are crucial for informing policy decisions and guiding future developments towards low-carbon construction practices.

Furthermore, the paper discusses the implications of these findings within the broader context of the UK's net-zero ambitions. It underscores the transformative potential of Passivhaus as a cornerstone of sustainable building design, capable not only of mitigating operational carbon emissions but also of significantly reducing overall environmental impact through thoughtful material selection and efficient building practices.

The study concludes by advocating for continued research and innovation in Passivhaus design, emphasizing the need for adaptive strategies that account for varying climatic and socio-economic conditions across the UK. It calls for enhanced collaboration between policymakers, industry stakeholders, and researchers to accelerate the adoption of Passivhaus standards and drive meaningful progress towards achieving national carbon reduction targets.

CATE 2024

Thermal Landscapes: Studying Thermal Transitions in Workplaces

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Abstract

Building standards promote uniform thermal environments, limiting thermal variance. Real building measurements show decreasing temperature variance and overall increasing indoor temperatures. While the Adaptive Thermal Comfort (ATC) approach broadens thermal comfort bands and offers energy benefits, design solutions are required to make broader temperature ranges a reality. The ATC approach, suggests that repeated exposure to the same thermal environments leads to adaptation, reducing the demand for thermal variation. However, some thermal contrast can be pleasurable, inducing alliesthesia and improving health indicators. This work discusses thermal zoning's potential to promote thermal variation, alliesthesia in architecture and energy conservation opportunities. Particularly, it investigates the role transitional spaces, like corridors and atria, can play in office buildings. Using simulation, we compare thermal and energy performance of different design variants of a multizone building energy model with a central atrium, a thermal buffer zone (corridor), and perimeter office spaces. We compare these variants to a baseline case that portraits a typical office building in Northern Europe, where all thermal zones are seasonally heated. The variants are: (i) unconditioned atrium, conditioned offices and corridors; (ii) unconditioned atrium and connected corridors, conditioned offices; (iii) unconditioned atrium and closed corridors, conditioned offices. The results show that thermal zoning can promote thermal variation leading to alliesthesia in compact, well-insulated buildings. It also highlights the thermal and energy benefits of using buffer spaces like corridors. In our case, a closed-off unconditioned corridor mediates the thermal contrast between conditioned offices and unconditioned atrium, saving appr. 40% of energy compared to the baseline. Finally, we discuss that defining conditioned and non-conditioned zones requires a careful design of the interface surfaces, as well as we discuss the limitations of common energy-related metrics to assess designs that explore thermal variation and alliesthesia.

A Decision-Support Tool to Increase the Uptake of MMC and Improve the Environmental Impact of the Irish Construction Industry

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Abstract

The availability of suitable living accommodation in Ireland has been cited as a fundamental concern by Irish society. The current housing system needs to meet its required targets for several reasons, including climate considerations, housing costs, and well-being. To alleviate the significant socioeconomic implications of the housing crisis, societal and environmental criteria must be considered. Alongside speed of delivery, health and safety, quality of life and enhanced build quality, stakeholders argue that Modern Methods of Construction (MMC) can advance the overall sustainability of the Irish construction industry and work towards the environmental goals set out in the 'Housing for All' action plan. However, the adoption of MMC is currently limited and a lack of suitable digital tools to fully grasp new materials, methods, and installation processes has led to widespread confusion and increased hesitancy to the transition.

This paper forms part of the "Platform4MMC" project which will develop an assessment tool to analyse and compare the viability of MMC against more traditional methods that can have a considerable, negative environmental impact. The research reports on semi-structured interviews with key stakeholders in the Irish residential sector, including governmental bodies, policymakers, contractors, developers, manufacturers, architects, end users, and many more industry representatives. These collaborators inform the project by providing their insight from completed off-site manufactured projects. To drive behavioural change, private and public bodies can use the tool's recommendations of the MMC products that best suit their criteria and pipeline, establishing a consistent level of demand to incentivise manufacturing capacity in Ireland. The interviews provide key learnings on the challenges and roadblocks to supplying adequate, sustainable housing in Ireland. A key performance indicator list was then developed with the stakeholder engagement findings, which identifies key metrics when assessing a projects suitability for MMC.

Comparing ambient and personal measurements of exposure to urban heat stress

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Abstract

This paper reports on a field study of personal exposures to summer heat stress in Elizabeth, NJ, USA, a medium-sized city that hosts an international airport, a shipping port, a petrochemical refinery complex, and a major transportation corridor in a densely populated metropolitan area. The study deploys a network of fixed outdoor sensors, a network of fixed indoor sensors, and mobile personal exposure monitors that are carried by residents. Study participants live in buildings operated by a public housing authority and include elderly retirees, high-school children, and working-aged people. Results show that residents' measured personal exposures to extreme heat are much lower than measurement of ambient conditions might suggest. Resident time allocation toward cooler, indoor activities explains much of the difference between ambient conditions and personal heat exposure. Individuals show that they adapt to changing environmental conditions, within constraints afforded by the built environment. This paper presents the Exposure Duration Curve as a useful graphical device for comparing the intensity and duration of environmental exposures.

Health and Wellbeing in the Buildings

Chair: Philomena Bluyssen

Understanding indoor air quality in nurseries

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Indoor air quality (IAQ) in nursery environments is essential for the health and development of young children. As their respiratory and immune systems are still developing, children are particularly vulnerable to the adverse effects of indoor air pollutants, including volatile organic compounds (VOCs), carbon dioxide (CO_2), and particulate matter (PM). This study examines the specific IAQ challenges within nursery spaces, where high occupancy, limited ventilation, and common materials can contribute to pollutant accumulation. By conducting continuous air quality monitoring in diverse nursery settings, this research analyzes pollutant levels over time, accounting for variations in occupancy, building design, ventilation practices, and external factors.

The study identifies peak pollutant periods and primary indoor pollution sources, such as cleaning products, building materials, and furnishings. It evaluates the effectiveness of strategies tailored to the nursery context, including natural and mechanical ventilation, air purifiers with HEPA filters, and maintaining optimal humidity levels to reduce airborne contaminants. Proactive measures like using low-emission materials, organizing regular ventilation, and limiting strong cleaning agents are recommended to maintain a healthy indoor atmosphere.

Findings highlight the importance of real-time monitoring and adaptive IAQ strategies in nurseries, as even low pollution levels can impact children's respiratory health, cognitive function, and overall well-being. Recommendations include educating staff and parents on IAQ management, implementing stricter IAQ standards, and incorporating design elements that enhance airflow and minimize pollutants. Addressing IAQ in nursery spaces not only supports early childhood development but also lays the groundwork for long-term health and resilience.

Influence of indoor air pollutants, temperature, relative humidity and building-related factors on perceived air quality (PAQ) in office buildings: evidence from a field study

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Abstract

As the climate changes, it is crucial to understand how indoor contaminants, rising temperatures, and fluctuating relative humidity (RH) — all influenced by global warming — affect perceived air quality (PAQ). Additionally, analyzing the impact of building-related factors (e.g., orientation, floor level) on PAQ is particularly important in office buildings where occupants often lack control over ventilation and shading systems. This research investigates the relationship between environmental factors, building-related factors, and PAQ in office settings. A field study was conducted in an office building in Bolzano (northern Italy). Carbon dioxide (CO_2), particulate matter (PM_1, $PM_{2.5}$, PM_{10}), total volatile organic compounds (TVOC), air temperature, and RH were continuously monitored for a 5-week period during winter 2023. PAQ was assessed through a "right-here right-now" questionnaire using a 7-point Likert scale (from “very dissatisfied” to “very satisfied”). Fifty-five individuals participated voluntarily, and their subjective feedback was correlated with thermal and indoor air quality (IAQ) parameters and building-related factors using a multiple linear regression analysis. Results showed that low RH values are associated with greater dissatisfaction with PAQ, while lower temperature values are linked to higher satisfaction with PAQ. Among the air contaminants, PM_{10} and $PM_{2.5}$ have statistically significant effects, with higher levels associated with lower satisfaction ratings. Orientation and office facing also influence PAQ satisfaction, with an outdoor view being more favorable than an indoor courtyard view, and a west orientation being the least favorable. The study demonstrates complex relationships between these predictors, their interactions, and PAQ satisfaction.

Assessing people's perception of indoor-environmental quality: Can we improve the signal-to-noise ratio?

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Abstract

This paper offers a critical assessment of the common approaches to elicit building users' perception of indoor-environmental conditions. Thereby, the main intention is to investigate if and to which extent such approaches have resulted in evidence-based criteria and guidelines for design and operation of buildings capable of providing adequate indoor-environmental conditions in buildings. Assuming that people's experience of such conditions is the target signal of the related scientific investigations, reflections on the limitations of current research approaches and guidelines may help reducing the noise in the signal detection process.

CATE 2024

Summertime Temperatures in the US Intermountain States' Parks – A Case Study of Utah

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Abstract

This study examines summertime temperatures in the US Intermountain states' parks – a case study of Utah state parks. The overarching goal of the study is to examine the possibility of elevated summertime temperatures and heatwaves in the US intermountain states' parks. The study selected Utah as a case study due to large presence of national and state parks in the state. The State of Utah has 5 national and 46 state parks. The research assesses the five most visited state parks in Utah. The study collected measured environmental variables at nearby meteorological stations for a year, but this paper considered analysis for the summertime (i.e., June – September of 2023). Across the selected parks, the daily mean temperatures exceeded the 28.5°C threshold between 52 days and 22 days out of 122 days, while the temperatures also exceeded the 32.5°C benchmark for up to 21 days in some locations. The results revealed the most visited parks are warmer for the most period of the year than the least visited parks. This factor may contribute to higher visitors reported in these locations than those with less visitors as they may become preferred locations during cold months. The study identified that even though elevated temperatures are observed in the most visited parks, visitors may prefer steady and warm temperatures to enjoy their time at parks than when there are uncertainties regarding the environmental conditions of such parks. The study presents valuable findings on the impact of elevated summertime temperatures on parks and thermal comfort of users. The investigation could notably impact the field of environmental comfort, planning, design, and management of parks.

Self-Learning Indoor Heat Warning System For Households

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Abstract

Due to climate change and rising temperatures worldwide, heat health warning systems HHWS have become important in accurately predicting heat waves. Most HHWS rely on the ambient temperature forecast. The German HHWS also considers the physiological heat load in the interior. However, this prediction is only made for a typical residential building with a typical residential use and not for a specific building in a specific environment. Hence, we developed, planned, designed, constructed and put into operation a self-learning algorithm with AI techniques to accurately predict the heat stress conditions in individual buildings based on monitored indoor conditions, weather data and weather forecast. First results after a two-year period of operation in 13 households show a good and reliable in-use performance – and some aspects for optimization.

Air conditioning as critical infrastructure in Arizona residential sector: Evidence from intermittently cooled homes

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Abstract

Climate change brings heatwaves of unprecedented severity and duration, creating an urgent need to better understand the role of air conditioning (AC) in supporting cooling capabilities, especially in regions facing extreme heat. In summer 2023, a heatwave in Phoenix, AZ, brought 31 consecutive days with daily outdoor temperatures reaching 43°C (110°F) or higher and a record of 55 total days exceeding this mark. In conjunction, the Phoenix metropolitan area recorded 645 heat-related deaths, 156 of which were indoors.

The presented analysis is based on data for 136 dwellings in the Phoenix area. Indoor temperatures, air conditioning load, and household energy consumption were monitored for four months, June through September, for the years 2021 to 2023. Some households change cooling set points to reduce AC-related electricity use. Analysis of temperature variation resulting from intermittent AC use provides insights into how indoor environments respond to being uncooled for different durations, which in turn helps improve understanding of both routine exposure to high temperatures and the severity of the risk of indoor overheating in the case of a power outage or AC unit failure.

Findings indicate that indoor temperatures frequently exceed risk thresholds, especially when AC units are off for longer durations and when outdoor temperatures are higher. There is a relatively short period for intervention in the event of an AC failure before the indoor thermal environment reaches temperatures considered to pose a health hazard to the residents. Households with limited income are particularly at risk due to a desire to reduce AC electricity bills, as well as the costs of AC repairs and replacement. Policy recommendations include developing a strategy to map AC performance in housing and capacity to offer assistance in the case of AC failure, particularly in vulnerable households and housing types.

Human Physiology and Adaptation

Chair: Hannah Pallubinsky

CATE
2 0 2 4

Temperature does not affect cognitive performance of men and women differently

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Abstract

Potential sex differences in thermal perception have been the subject of various investigations both in controlled experiments and in field studies. Nevertheless, potential sex differences in cognitive performance have not been investigated as thoroughly. This study aimed to address this gap by investigating possible sex differences in cognitive performance and the impact of ambient temperature on cognitive performance of individuals with similar characteristics. A total of 48 participants (50% female) took part in controlled experiments. Participants' activities during the experiments simulated office work. The experimental protocol consisted of exposing all participants to three different temperatures (20, 25, and 30 °C) to elicit a cool, neutral, or warm sensation, respectively. All other environmental parameters were kept constant, and other parameters likely to affect the results were controlled. Different tests were used to assess cognitive performance including a reasoning test and a multiplication test. Data analysis included descriptive statistics and linear mixed effects modelling. The results showed no significant effect of indoor temperature and/or sex on cognitive performance. The study also revealed that the indoor temperature did not affect cognitive performance differently in men and women with similar characteristics. Our results are in the context of more fundamental research and add to previous findings showing that cognitive performance can be maintained over a wide range of indoor temperatures.

Analysis of the human body's exergy consumption in various environmental circumstances

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Abstract

The evaluation of human body exergy is an important idea derived from the concepts of thermodynamics, explored on this study. To begin, a two-node model is used to solve the transient energy balance, and then the exergy consumption of the human frame is determined the use of enter and output exergy. Input exergy consists of elements including exergy from the metabolic rate, inhaled exergy, exergy from radiation enter, and exergy from liquid water produced withinside the core and shell. Output exergy encompasses exergy stored withinside the shell and core, exergy from exhaled air, exergy from sweat secretion, convective exergy output, and radiative exergy output. The study investigates various relationships among exergy consumption, air temperature, and the human body`s metabolic rate. Findings imply that decrease humidity levels result in higher exergy consumption in comparison to higher humidity levels. Additionally, an increase in air temperature results in expanded exergy consumption.

Psycho-physiological responses in spatial transitions during hot and milder summer days

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Abstract

People's thermal sensations and adaptation after a spatial transition can affect how they behave in long-stay rooms in buildings. This study evaluated how transitioning from an outdoors to an office environment affects human psycho-physiological responses. The transition parameters (duration, walking length and exposure) were standardized, and environmental variables such as outdoor air temperature, indoor air temperature, relative humidity, air speed, and globe temperature were measured. Physiological signals comprised skin temperatures monitored over 10 points in the participants' bodies and psychological questions focused on overall thermal sensation and thermal pleasure. This study involved seven experiment days with 12 subjects (six male, six female) in a Brazilian subtropical climate. Mean skin temperatures were increased by about 1 K during hotter days compared to milder days during outdoor expositions. Such a variation may lead to different perceptions of indoor environments, also with a relatively larger period to achieve neutral votes after transitions. During hotter days, longer periods (60 min) were needed to achieve pleasant perceptions of the indoor environment compared to reaching neutral thermal sensations (20 min). These results emphasized that outdoor exposures during a typical workday affect both descriptive and affective dimensions of human thermal comfort in indoor environments.

Hot and stuffy: How poor indoor air quality and high temperature affect human cognition and health

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Abstract

Humans spend 90% of their time indoors, which makes the indoor environment an important factor for cognitive performance and health. Past studies have shown that poor indoor air quality from insufficient ventilation of indoor spaces negatively affects cognition performance and leads to adverse health effects due to air pollutants accumulating in the room. High temperature indoors is also assumed to negatively affect cognitive performance. However, the physiological mechanism and subsequent health implications are largely unknown. Hence, enhancing mechanistical understanding of how poor indoor air quality and elevated temperature affect cognitive performance is necessary. Additionally, studies which examine the impact of the indoor environment on building occupants usually investigate effects of air quality and temperature in isolation, but much less is known about the interaction of these two factors, and a potential additive effect. Being exposed to an insufficiently ventilated room with no air conditioning in summer is, however, a common scenario in office and school buildings, underpinning the importance of examining how bad air quality and elevated temperatures together affect cognition. Therefore, the aims of the present study are 1) to examine the physiological mechanism affecting cognitive performance during exposure to poor indoor air quality and high temperature; and 2) how these two factors interact with each other in their effect on cognition. It is assumed that poor indoor air quality and elevated temperature are associated with declining cognitive performance, which co-occurs with a restricted lung behavior and elevated carbon dioxide levels in the blood. It is also assumed that temperature moderates the effect of indoor air quality on these outcomes.

Common Practices in Physiological Data Collection Studies in the Thermal Comfort Field

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Abstract

The improved accessibility of non-invasive sensing technology has increased interest in measuring individual physiological parameters in thermal comfort studies, resulting in a wealth of valuable thermal physiological data. However, inconsistencies in data collection methodologies, application procedures, experimental descriptions, and data presentation have led to fragmented efforts. This paper conducts a meta-analysis of recent literature on thermal physiological data collection in laboratory studies, highlighting the inconsistencies and opportunities for greater alignment. Our findings show a lack of consensus on metrics measurement and reporting, inconsistent data treatment, arbitrary quality control measures, and limited access to original data, all hindering comprehensive meta-analyses. Despite these inconsistencies, we identified common methods and easily standardizable features, which can serve as starting points for unification. To aid in standardization, we propose a scheme for metadata reporting and created a beta version of BEAT (Building Experiment Assistant Toolkit), an interactive online dashboard platform comparing thermal physiological experiments. By creating the tool, we hope to initiate the creation of a global physiological metadata database that leads to a standardization of data collection and reporting and unifies individual research efforts globally.

CATE 2024

Establishing Maximum Safe Indoor Temperatures for U.S. Residential Buildings

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Abstract

Heat is a leading weather-related cause of death worldwide and heat waves are increasing globally in terms of frequency, duration, and intensity. Global heat-related deaths could quadruple by midcentury. As with many environmental hazards, numerous factors impact how heat might affect any given person and there are significant gaps in our understanding related to indoor heat and its effect on health. Despite growing interest in establishing standards and guidelines, there is currently no clear consensus on a safe maximum upper limit for indoor temperature. There is conclusive evidence of links between high outdoor temperatures and human health yet research on this correlation does not typically explicitly consider indoor heat exposure. Considerably more research has been completed on healthy, active individuals than for more heat-susceptible populations and the impacts of moderate heat stress on the health of large populations are not well understood.

We conducted a literature review on the impact of indoor thermal conditions on health, recognizing that air temperature alone cannot describe thermal exposure. We introduce the concept of a standardized maximum safe indoor temperature, defined for still air conditions, 50% relative humidity and mean radiant temperature equal to air temperature. Equivalent temperatures with respect to the thermal load on the body can then be calculated for various air velocities, humidities or mean radiant temperatures using the standard effective temperature (SET) model. For U.S. policymakers, we propose adopting a standardized maximum safe indoor temperature of 28 °C. We recognize that the adoption of standardized maximum safe indoor temperatures may vary around the world, but the framework we propose to adjust the standardized upper limit for humidity, air motion, and radiant temperature could be used globally. We also identify important knowledge gaps to guide future research on the relationships between heat and health that could support informed cost-benefit analyses.

Innovations in Personal Thermal Comfort Technology

Chairs: Samuel Domínguez / Charlei Huizenga

Low energy comfort in cool conditions with heated shoes

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Abstract

A newly developed personal comfort system (PCS) made by a pair of heating shoes was evaluated in a climatic chamber with human-subject tests. Seventeen subjects participated in 51 1 hour and 45-minute tests. The chamber temperatures were set at 21°C, 20°C, and 19°C. Subjects experienced the different indoor conditions with and without PCS. When they were provided with the heating shoes, they had full control over the device through a knob located in a light bum bag. Tests with and without PCS and the sequence of tested indoor temperatures were randomized. Subjective responses about thermal sensation, thermal comfort and thermal acceptability were collected during the tests.

The results show that the heating shoes impact subjects' thermal sensation and improves acceptability. The shoes provided acceptable indoor conditions for at least 80% of the subjects down to 19°C.

Subjective assessment to desk level personalized ventilation: A study from field

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Abstract

The uniform cooling method in a workspace provides the same comfort conditions to all the occupants without accounting for individual comfort requirements, leading to uncomfortable conditions, excess amount of energy consumption, and risk of exposure to cross-contamination. Thus, a personalized ventilation (PV) air distribution method can be used effectively to provide the occupant's individual comfort by enabling them to control their immediate thermal environment. Most of the studies conducted previously in literature were from personally controlled environmental chambers aiding with simulation studies. There are very few studies reported from the field, which is crucial to studying the PV system performance under real dynamic conditions, especially in the case of tropical regions of India.

This study in our preliminary level experimental work, aims to evaluate the subjective responses to personal level conditioning under three different setpoint temperatures of 24°C, 26°C, and 28°C and supply airflow rates varying between 20 l/s to 34 l/s in combination with a ceiling fan from a field. The main objective of this work is to assess the subjective perception and acceptance of the elevated airflow rates, and thermal environment provided by the personalized ventilation system. The limitations of the work are that no personal controls over temperature and flow rate are provided, rather subjective assessment was carried out under pre-set conditions.

The subjective votes to their thermal environment, perceived air quality (PAQ), and air movement are compared under three setpoint conditions, and results reveal that under the 26°C, 85% RH condition, 63% votes indicated comfortable without any change in temperature, flowrate, while 47% votes in remaining two conditions indicated comfortable without any change. These results help carry out a large-scale experimental study in an office environment for an effective design, and operational strategies for PV systems in practice.

CATE 2024

Exploring the airflow generated by ceiling fans on a human body: an experimental study with a thermal manikin

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Abstract

Ceiling fans can provide comfort cooling in low-energy buildings, enabling the use of warmer room temperature set-points. While increased air movement through ceiling fans is an effective way to provide comfort in warm and humid conditions, the localized cooling impact on individual body parts can vary significantly based on the speed and direction of the airflow. This variability can influence local thermal sensation and hence the overall comfort. This study investigates how a ceiling fan impacts the heat flux and convective heat transfer coefficient of the different body-parts, using a thermal manikin in a living-room setting. This study explores the heat transfer dynamics around a clothed thermal manikin in a controlled ambient with a typical dining room furniture arrangement. The thermal manikin, operating in PI controller mode, measured the heat flux required by 27 different body-parts to maintain a constant skin temperature. The ceiling fan's impact is examined under two flow directions (Direct and Reverse), across three fan speed levels, and two seated positions around a dining table setup. Measured parameters include heat flux of each body part, air temperature, and air velocity near the manikin at four heights, which were used to calculate the convective heat transfer coefficient for each body part, allowing for a detailed analysis of the fan's cooling effect on specific body segment. The findings reveal distinct differences in the convective heat transfer coefficients under Direct and Reverse flow directions and across the two positions, suggesting potential variations in thermal sensation. Direct airflow correlates with increased cooling effect, particularly affecting the head, face, forearms, and hands, while reverse airflow enhances air velocity at feet level. The detailed characterization of localized cooling effects under various fan configurations enables more accurate modeling of human thermal response, leading to optimized control strategies for ceiling fans.

Experimental Investigation of Evaporation Dynamics through Intermittent Mist Flows: Exploring Duty Cycles and Frequencies

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Abstract

This research investigates the potential of airflows cooled by intermittent misting in enhancing evaporation via a series of regulated wind tunnel experiments. The study evaluates the impact of intermittent mist flows versus continuous misting, using the same total amount of water, under consistent airflow conditions. Five experiments were conducted: one as the baseline and the other four examining the effects of different frequencies and duty cycles. The variations were methodically increased and decreased to identify the fundamental parameters affecting intermittency. The findings indicated that intermittent mist flows generated reduced temperatures and elevated relative humidity levels compared to continuous misting. Reduced duty cycles and frequencies (down to 37.5% and $0.025\,Hz$, respectively) exerted the most pronounced effects, with temperature reductions of up to $-1.2°C$ and humidity increases of up to 6.8%. As duty cycles and frequencies increased (up to 75% and $0.1\ Hz$, respectively), the impact diminished; for instance, temperature reductions were as low as $-0.3°C$, and humidity increases were limited to 2.4%, approaching the effects of continuous misting. The study's results showcased that employing intermittent mist spray patterns can probably enhance the overall evaporation rate. Possible contributing factors include the prevention or reduction in the size of local saturated regions during lower on periods and increased off periods, enhanced flow instability, and improved heat transfer dynamics facilitated by phase-change cooling instead of single-phase cooling. The dataset produced from these experiments serves as a significant validation resource for computational fluid dynamics (CFD) models, facilitating further analysis of the mechanisms underlying these enhancements and aiding parametric assessments.

A novel conductive-radiative Personalised Environmental Control System (PECS): optimization and performance enhancement

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Abstract

This study presents the optimization of a novel conductive-radiative Personalized Environmental Control System (PECS) in the form of a heated desk, designed to improve ergonomics and reduce energy consumption. Building on previous prototypes, the desk maintains localized comfort in ambient temperatures as low as 17°C, with enhanced user control of upper and lower heating surfaces. Three configurations of desk heating surfaces were tested using a thermal manikin in a climatic chamber, evaluating heat loss and heating effects (HE – quantifies how much a PECS can correct the room temperature to recreate the neutral sensation, unit in K). The most ergonomic and energy-efficient configuration, Desk B, features a large lower heating surface and a smaller upper surface, providing localized warmth without risking damaging sensitive desk equipment. Key findings show that Desk B consumed 69-82% less energy than previous PECS models (Rugani et al., 2023), with power consumption ranging from 31-52 W, compared to 170 W in earlier prototypes. The average Heating Effect (HE) ranged from 1 to 1.5 K across all configurations, with localized HE values reaching 2.5 to 4 K in target areas like hands, forearms, and thighs. A peak of 9.7 K was recorded when direct hand contact with the heating surface occurred, demonstrating effective heat localization at reduced energy consumption levels. This optimized PECS demonstrates significant potential for energy-efficient, personalized heating solutions in office environments.

How crucial are Personalised Environmental Control Systems (PECS) in newly constructed offices? A comfort-energy case study perspective

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Abstract

This study investigates the potential benefits of integrating Personalised Environmental Control Systems (PECS) in newly constructed office spaces, focusing on energy efficiency and thermal comfort. Two modern offices in Lucca and Massa, Italy, were analyzed through a combination of on-site data sampling and dynamic Building Energy Simulations (BES). Despite being equipped with contemporary HVAC systems, these offices often fall short of achieving optimal comfort and energy consumption levels, particularly under varying occupancy conditions. The findings demonstrate that PECS could significantly enhance energy efficiency by allowing for localized environmental control, especially in under-occupied offices. Implementing PECS in the studied offices could lead to energy savings of up to 85% in both winter and summer for Lucca, and up to 85% in winter and 42% in summer for Massa. The effectiveness of PECS is particularly evident in environments with extensive glass surfaces, such as the Massa office, where traditional HVAC systems struggle to maintain comfort without incurring high energy costs. Additionally, the study reveals that even when all occupants use PECS simultaneously, the impact on overall energy consumption remains minimal, preserving the efficiency gains. These findings highlight the importance of integrating PECS in modern office design as a forward-thinking approach to achieving personalized comfort and substantial energy savings.

CATE
2024

Boosting personal cooling with water: comparing a desk fan and evaporative coolers

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Abstract

In a warming climate, energy-efficient cooling strategies are an urgent need. Using personal cooling systems associated with increased setpoint of the ambient temperature is an effective way to achieve that goal. In a previous study, four types of personal fans were tested in a semi-controlled environment, and the evaporative cooler (EC) was preferred over the other fans. Nevertheless, the EC was too expensive and not cost-effective for participants. To estimate the cooling effect, we performed a chamber experiment with a thermal manikin comparing the heat loss produced by a fan and two evaporative coolers (A, B) with different characteristics and cost. Results show EC Model B had the highest cooling effect, equivalent to 2.9 °C reduction of perceived ambient temperature, and the best performance — generating 0.5 °C cooling per Watt of power used. While Model A reached a lower cooling effect, with a maximum of 2.2 °C when wet, and when it was wet, it produced the same cooling effect as the fan, 1.4 °C. These findings highlight the advantages of well-designed evaporative coolers and underscore the need for further research on this off-the-shelf personal cooling solution.

Optimizing Indoor Comfort: A Sustainable Fusion of Personalized Ventilation and Innovative Passive Ventilation System

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Abstract

Improving indoor air quality and ensuring thermal comfort in hot and humid climates typically require energy-intensive HVAC systems. This paper presents the integration of a chimney-driven liquid desiccant dehumidification loop and an indirect evaporative cooler (CDL-IDEC) with an adsorption-thermoelectric cooling based personalized ventilation device (PVD) as a sustainable and energy-efficient alternative. The system's design and operation were optimized using a Neural Network-Particle Swarm Optimization (NN-PSO) algorithm for an office space in Qatar under extreme ambient conditions. The integrated system was able to supply $115\ L/s$ of airflow, maintaining a macroclimate at $28.12°C$ and 69.8% relative humidity, while delivering conditioned air to the occupant's microclimate via the PVD. The results show a significant reduction in energy consumption, with the CDL-IDEC and PVD system using $12\ kWh$ electrical energy over a one-hour period, compared to $37.5\ kWh$ for a conventional HVAC system. This energy savings of $25.5\ kWh$ translates to a $2 per hour operational cost reduction. Additionally, the system reduced CO_2 emissions by $11.4\ kg$ per hour. These findings demonstrate the effectiveness of the proposed system in reducing both energy consumption and environmental impact, while successfully ensuring thermal comfort and IAQ.

Climate-Adaptive Urban Housing in Istanbul: Integrating the Vernacular Bay Window as a Functional and Environmental Device

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Abstract

The global climate change and other dynamic transformations experienced by cities, including population growth, socioeconomic shifts, and inflation have imposed inadequate housing conditions. In Istanbul, rising housing demand increased hastily constructed housing blocks in the outskirts, leading to displacement. The city's distinctive climate varies between temperate Mediterranean and temperate Oceanic, characterised by warm to hot, moderately dry summers with a 24.4°C average and cool to cold, wet winters with a 7.6°C average. The future climate, 2080 A2 (most extreme), shows a 4-6°C temperature increase, causing extreme heat during summer. The new residential developments will need to find adaptive solutions that create environmentally comfortable spaces to accommodate climate changes and variations. This research was inspired by the bay window, a traditional architectural feature in Istanbul. The research was conducted by modelling a range of bay windows to identify the potential of functional adaptability and environmental benefits. During cold and mild weather, the bay window serves as a passive solar collector, utilising shutters to further regulate the energy exchanges through the building fabric. In the warm season, the bay window provides a pleasant space that projects outward, interacting with the street. Dynamic thermal simulations with Energy Plus have shown that integration of the bay window can improve winter and mid-season thermal comfort considerably by raising the module's temperature by 5-7°C compared to the base case without a bay window. In summer, overheating is prevented with solar control strategies. Thus, the bay window acts as a climate-adaptive architectural device throughout the year. The paper will present further studies to illustrate and discuss the range of applications, and the functional and environmental potentials of the bay window for contemporary and future residential developments that consider future climate change scenarios in Istanbul.

Understanding Ceiling Fan Usage in Multi-Unit Residential Buildings: Patterns, Environmental Influences, and Impact on Comfort

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Abstract

Ceiling fans are used in residential environments to enhance occupant comfort by promoting air circulation, which increases heat dissipation from the body and lowers perceived temperature under certain conditions. When used alongside air conditioning systems, ceiling fans can maintain thermal comfort while reducing cooling demand and the associated energy costs. Despite these benefits, studies on ceiling fan usage behavior and impacts in multi-unit residential buildings (MURBs) are lacking.

This study aims to ceiling fan usage behavior in multi-unit residential settings, focusing on the indoor environmental factors associated with fan operation and the relationship between occupant comfort and fan use. The study continuously monitored various indoor environmental quality (IEQ) parameters and residents' ceiling fan on-off states using sensors in 14 occupied residential suites in Canada during summer months. Concurrently, occupant IEQ comfort was recorded through point-in-time surveys conducted with smartwatches, and additional feedback on ceiling fan usage was gathered through supplementary surveys.

The paper presents a descriptive analysis of ceiling fan usage patterns, occupant comfort levels, and corresponding in-suite IEQ conditions. Key findings reveal that ceiling fan usage peaks in summer, primarily due to perceived stuffiness and excessive heat. Significant correlations were found between fan use and both air temperature and relative humidity (RH), with insight into how fans may improve comfort in humid conditions. The analysis further indicates that the use of ceiling fans can potentially enhance thermal comfort, as ceiling fan operation was frequently observed during the "not comfy" to "comfy" transitions. These analyses aim to highlight the practical benefits of ceiling fan usage in residential settings and provide actionable insights for optimizing comfort and efficiency.

New Materials for Thermal Comfort

Chair: Jens Pfafferot

Impact of aging effect on the energy performance of an ultra-emissive paint for radiative cooling of building roofs

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Abstract

Radiative cooling is an efficient tool to address problems associated with overheating, such as excessive energy consumption and thermal discomfort. These issues are, if possible, even more worrying in the case of social housing built in Spain in the middle of the last century, which generally suffer from a lack of energy insulation measures that accentuates the impact of overheating on their living conditions.

This paper analyzes the energy effect of the application of a recently developed ultra-emissive paint on the roofs of a typical case of social housing built in the decade of the 1960s in the city of Seville.

This analysis takes into account the impact of the effect of aging on the reflective properties of the paint and the associated consequences on the energy performance of the roof of the considered building. For this purpose, the thermal flux through the roof is evaluated in a variety of scenarios, including different aging and maintenance patterns.

The results of the comparison between the initial roof and the cool roof obtained after the application of the ultraemissive paint are presented. These results allow us to establish that the radiative paint considered can provide substantial reductions in the heat flux through the roof in all the scenarios analyzed, with consequent positive effects on interior thermal comfort and on the reduction of energy consumption, especially in hot seasons and under heat wave scenarios.

Living Wall Water Balance Model for Smart Irrigation

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Abstract

The impacts of climate change are especially evident in urban settings, manifesting through the urban heat island effect. This phenomenon is exacerbated by the rising density of built-up areas forming street canyons, which leads to a decrease in green spaces and an increase in the heat capacity of the built environment. The urban areas such as cities need to become heat-resilient which can be achieved with implementation of climate adaptive building design.

Green building envelopes, such as green roofs or living walls (LWs), are particularly interesting to researchers and building designers due to their numerous environmental benefits (such as acting as a sink for CO_2 and other pollutants, noise reduction, mitigation of the urban heat island effect, retention of rainwater runoff, and enhancement of biodiversity). They also improve microclimatic conditions and living comfort in cities.

In many cities, particularly in hot climates or during heatwaves, water availability becomes a significant issue. Therefore, the hypothesis is that the demand for irrigation water can be minimized by utilizing smart irrigation system that originates from weather forecasts.

There is a lack of research focused on accurately assessing the thermal and hydrological responses of LWs. Consequently, this study experimentally investigates a modular LW with lightweight mineral wool substrate and as a novelty proposes a detailed water balance model with the emphasis on evapotranspiration modeling, which crucially affects the irrigation demand.

The measurements of evapotranspiration rates of LW module with weighing method are used for calibration of evapotranspiration model. The measured parameters of LW water balance (irrigation, rainfall, water saturation ratio in substrate and runoff) are used for validation of empirical evapotranspiration model which is based on meteorological data (ambient air temperature and humidity, solar radiation, wind speed and precipitation amount). The study concludes that by using this model, the irrigation demand decreases.

CATE 2024

An evaluation of the economic and technical aspects of employing air source heat pumps integrated with thermal energy storage for residential space heating in Canada

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Abstract

Reliance on natural gas boilers for space heating in Canadian multi-unit residential buildings (MURBs) leads to substantial CO_2 emissions. Electrification of space heating systems can aid in decarbonizing space heating, particularly when integrated with renewable energy sources (RES), such as solar thermal. However, the challenge remains to match heat supply with demand. Thermal energy storage (TES) can be employed to store heat from solar collectors (SC), thereby reducing the reliance on boilers. Additionally, replacing natural gas boilers with electric heat pumps (HP) to supplement renewable sources, such as solar thermal, is a promising alternative to fossil fuel heating sources. This paper evaluates the techno-economic feasibility of different heating systems for decarbonizing the Canadian residential heating sector. Using simulation methods, it assesses hourly energy flow in the central heating plant of a contemporary MURB connected to the electricity grid. Four different heating system configurations (Boiler, HP, SC, and TES) are assessed by simulating hourly energy flows, based on central plant operation data collected in a MURB in Toronto, Canada. Key aspects evaluated include the required capacity of equipment, capital cost of different systems, and the cost of decarbonization. The levelized cost of heat, CO_2 emissions, and share of RES are compared and the peak electricity load resulting from the use of HP and GHG emissions are assessed, considering the impacts of different emission factors for electricity. Although, the system configuration with an HP alone has the lowest cost of decarbonization but adds a significant peak load on the electricity grid infrastructure. The results indicate that a heating system consisting of an SC, TES, and HP is a cost-competitive option for decarbonizing heating in dwellings.

CATE 2024

Financial Analysis of Domestic Renewable Energy Solutions

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Abstract

A financial analysis based on Eurostat, SEAI and gas and electricity prices available in the marketplace and price ratios is presented for solar PhotoVoltaic (PV), Heat Pump (HP) and Electric Vehicle (EV) projects.

Key findings from the analysis:

1. The variance between statistical energy unit prices (e.g. Eurostat) and those available in the marketplace can be considerable, and could lead to misleading conclusions.
2. The impact of smart meter tariffs can be considerable when carrying out financial analyses.

The use of appropriate market tariffs can have significant impact on the affordability of renewable energy systems which is key to ensuring the social equity and inclusion objectives are achieved.

The paper highlights the value in carrying out detailed analysis based on market tariffs and tailored case studies in order to obtain accurate evaluations of renewable energy options.

Nanomaterials in building performance: balancing innovation with environmental and health impacts

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Abstract

In the quest to improve building performance, nanomaterials have emerged as promising components with the potential to transform construction practices. This investigation explores how these advanced materials can enhance building performance while addressing their environmental and health impacts through Life Cycle Assessment (LCA).

Nanomaterials offer innovative solutions for enhancing construction practices, with capabilities that could revolutionize building performance. However, while their functional benefits are well-documented, there is a significant gap in understanding their full environmental impacts. This gap is crucial as the construction industry increasingly emphasizes sustainable building practices.

The comparative analysis of scientific papers on LCA applied to nanoparticulated building materials underscores this gap. Although nanomaterials show promise in enhancing building functionalities, existing research often prioritizes their performance characteristics while neglecting a comprehensive evaluation of their environmental effects over their entire life cycle. This lack of holistic assessment poses challenges for their broader adoption in sustainable building practices.

To address this, a comprehensive approach utilizing LCA to assess the sustainability of nanomaterial applications is proposed. This approach will provide a clearer understanding of both the benefits and potential environmental risks associated with these materials.

This research advocates for a shift towards holistic assessment frameworks that not only highlight the performance enhancements offered by nanomaterials but also ensure their sustainability. By integrating these assessments, we can better align innovations of nanomaterials with broader environmental goals, ultimately leading to more effective and eco-friendly building solutions.

CATE 2024

Analysing Passivhaus EnerPHit standard in a tropical rainforest climate: Retrofitting a terraced house to identify effective insulation materials for energy efficiency

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Abstract

The Passivhaus principles have been applied mainly in European countries, where the requirement of resilient and greater energy-efficient levels became essential in buildings due to human actions leading to a rise in global temperature. However, the feasibility of the Passivhaus principle has rarely been tested in hot and humid climates, where the high humidity and temperature levels reduce the body thermoregulation and demand constant mechanical cooling in buildings. One of the highest potential heat rises will take place in northern Brazil, where, despite its lower population density, the country's seventh-largest city, Manaus, is expected to face a significant increase in electricity load and urban heat island effects due to the use of air-conditioning. This research aims to address these challenges by following Passivhaus principles and understanding which insulation materials are most effective in decreasing the active cooling demand in a building, reducing its energy consumption and operational carbon. Therefore, using EnerPHit criteria as the guide, the practical approach to achieving energy efficiency and comfort levels in a tropical rainforest climate will be investigated. A comparative analysis was conducted between four insulation materials (mineral wool, wood fibre, extruded polystyrene and polyurethane foam) and passive design strategies on an existing terraced house in Manaus, Brazil, as a typical house in the city. A dynamic thermal simulation software, DesignBuilder, was used for the building assessment. The results delivered quantitative evidence for designing approaches and evaluated the Passivhaus principles for tropical rainforest climates. A key finding of this research was that wood fibre performed with the lowest building energy demand compared to the other three materials, providing resilient values throughout future weather conditions. The minimal thickness achieving the standard's U-value was sufficient to reach a 42.57% lower primary energy demand than the EnerPHit criteria. Renewable energy sources and dehumidification are recommended to lower cooling demand and indoor relative humidity without compromising the total building energy demand.

Steel and glass - once fashionable architecture, now problematic in the context of climate warming. A case study on the example of a building located in Central Europe

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Abstract

The paper evaluates the impact of modifying the thermal properties of windows in rooms with a significant glazing area on indoor air quality and the energy consumption associated with its maintenance. This is particularly important in light of the growing evidence of climate change, with rising outdoor temperatures being a major factor in increasing energy costs, degrading indoor air quality, and impacting the health and productivity of building occupants. Maintaining comfortable thermal comfort conditions is becoming increasingly difficult due to the increased demand for cooling, which poses a challenge for large open-plan offices in almost fully glazed existing buildings with non-operable windows. The paper presents the measurement results for such a space where employees consistently report discomfort, overheating, overcooling and stuffiness, and the results of simulations carried out in WUFI Plus software. Additionally, CO_2 emission from the HVAC system was calculated.
In the investigated building, replacing glazing with those of a lower U-value resulted in a 21% reduction in CO_2 emission compared to the existing window characteristic. If the windows are not replaced, but their g-value is changed (e.g., by applying solar film), reductions of up to 5% can be achieved for U=1.5 W/(m²K) and 8.5% for U=0.9 W/(m²K). However, changing the g for a large glazing area while keeping the U constant can result in up to a 7% increase in heat loss during winter.

Comparison of impact of ventilated roof and insulated roof in temperate, composite and warm humid climates of South Asia

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Abstract

One of main passive design features recommended for the cooling dominated climates in India and other countries of South Asia is that of roof insulation. It is also one of the core provisions for complying with several building energy codes and performance standards. This paper assesses the thermal performance of four different roof assemblies for an existing three floor residential building. The study analyzed four roof assemblies: (1) a Business-as-Usual (BAU) case with a RCC roof, (2) a Reflective Roof with high Solar Reflective Index (SRI) paint on RCC, (3) Ventilated Roof with a 50 mm air gap and a corrugated sheet applied with high SRI paint and (4) an Insulated Roof with insulation directly over the RCC with high SRI paint. The roof assemblies were further simulated in three climate zones of: Bengaluru, India (temperate), Nepalgunj, Nepal (composite) and Chennai, India (warm and humid).

Results indicate that in temperate climates like Bengaluru, shading the roof with high Solar Reflectance Index (SRI) can be equally or more effective than roof insulation in reducing heat gains. The ventilated roof assembly showed a 15% reduction in the annual cooling load compared to the insulated roof in this climate. However, its effectiveness reduces when the avg. max. of dry bulb temperature (DBT) exceeds approximately 30°C, where insulated roofs become more beneficial. The study shows that a ventilated roof is an effective and affordable option for climates with an avg max. of DBT at or below 30°C. It also highlights the need for the inclusion of more design options in building codes to reduce roof heat gains. Analyses for other roof assemblies need to be carried out, with updated climate data, to suggest solutions that are implementable and cost-effective.

Nature-based Solutions

Chair: Denise Duarte

CATE 2024

Exploring the microclimatic conditions and cooling effect of trees in UK primary schools during summer

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Abstract

Lack of thermal comfort in schools affects children's well-being and educational outcomes. Frequent heatwaves in recent years have exacerbated the overheating issue in schools, especially in Northern European countries, such as the UK, which are unprepared for the global temperature rise. Previous studies have mainly focused on the indoor environment, although children use both indoor and outdoor areas for school activities. Additionally, there is various evidence that green infrastructure, such as trees, offers a range of benefits for the urban environments and their occupants. Therefore, this research investigates the impact of tree shade on the microclimatic conditions of schools during summer.

Micrometeorological parameters, including air temperature and globe temperature, were measured in both sunlit and tree-shaded locations in four primary schools in Coventry on sunny summer days in 2023. Thermal imagery was used to compare the surface temperature of different materials in sunlight and shade. Tree shade proved to be a significant heat mitigator, reducing air temperature and mean radiant temperature by a maximum daily average of 3.3°C and 10.9°C, respectively. Widely used materials in schools, such as asphalt and artificial turf, had the highest surface temperatures in sunlight, exceeding 50°C and 60°C, respectively. The surface temperature of natural grass, however, remained below 35°C.

This study concludes that optimising tree shade and greenery and replacing artificial materials are necessary for effective heat mitigation. Therefore, to provide thermally comfortable and sustainable school environments, and reduce cooling demand, a design policy for outdoor environments in schools is essential.

Thermal Response of Blue-Green Roof Under Extreme Drought Conditions

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Abstract

Green building envelopes have been emerging as an important tool for mitigation of urban heat island effects caused by rapid urbanization. The adaptive ability of vegetation to cool itself through evapotranspiration can effectively improve the thermal comfort in urban environment. However, the transpiration mechanism requires water for its functioning. This study focuses on prolonged water shortage periods which are common in dry climates and are even expected to be more and more frequent in other climates due to climate changes. While irrigation offers a solution to water scarcity, it is often not desirable, or in some extreme cases even prohibited, to use drinking water for irrigation. A new design of green roofs with water storage layer (blue-green roof) has emerged in recent years to help with the water shortage periods by storing rainwater. But even this is not adequate for extreme climate conditions. The subject of this research is an extensive blue-green roof with water storage layer and drought resistant sedum vegetation. The experimental results include measurements of evapotranspiration, substrate moisture content and temperatures of the blue-green roof test module. The test module is exposed to prolonged water shortage periods. The ability of vegetation to recover after water stressed conditions is evaluated. The thermal response which includes the temperatures and water content across various layers is shown. Special attention is given to surface temperature at water stress conditions, which is compared to temperatures of conventional roofs. A validated water balance model is used for the purpose of expanding the results to different climates. The typical meteorological year data for various locations is used for year-round simulations, which show the expected duration of water shortage periods. The paper concludes that while performance of green roofs in extreme climates is reduced, positive benefits remain in comparison to conventional roofs.

Climate adaptation from city to street scale in Sao Paulo: linking science to the city life

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Abstract

Cities are facing unprecedented climate change, urging for adaptation to the extreme heat. In the last 10 years, the development of climate adaptation plans increased in developed countries, but not as much in developing countries. Between 2000 and 2018, 48 thousand people died due to extreme heat only in Brazil, and the temperatures increased fourfold since the 1970's. In São Paulo, it is possible to observe an uneven pattern of green distribution, as well as land surface temperature differences, which tends to be higher in arid areas, in the densely built-up and populated periphery, picturizing a very clear link between socioeconomic vulnerabilities and the arid heat. In this context, the main goal is to explore thermal remote sensing data, and microclimate simulations, aiming climate adaptation, from city to street scale, potentializing ecosystem services for climate regulation. Linking science to city life, the target is to benefit people in the crowds, either around public transportation hubs or active mobility routes, among the ones more exposed and vulnerable to heat waves. In the microscale, simulations on ENVI-met show the microclimate effects of greening in lack of space, planting trees in parts of parking spaces and along roads in a high pedestrian traffic area next to a very busy train station in São Paulo. The simulations show that vegetation is capable of reducing air temperature in circa 0,97°C, but the most significant effect is found in the reduction of MRT (-22,45 °C), LST (-18.94 °C) and PET (-9,34°C), reducing thermal stress. From the outputs, it has been possible to better understand the link between people and pixels in a territory with plenty of environmental and socioeconomic contrasts, to narrow it down to the local scale informing urban planning and regulations for climate adaptation.

Adding options to cities' urban heat island mitgation: The Smart and Urban Tree Approach

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Abstract

The present contribution highlights approach, applied methods, and results of a recently conducted research project named Smart and Urban Tree. Thereby, the authors focussed on critical spots in typical European City centers, which are characterized by little to no blue-green infrastructure, high population densities, large assemblies of mineral surfaces of the existing building stock, and – above all – a heavy competition between usages and space consumption. Given that this competition for space is happening on sealed surfaces, and very often also below (energy and gas lines, water pipes, sewers, instances of public transport, etc.), traditional approaches of implementing blue-green infrastructure are often difficult (resulting in very small interventions) to (even) impossible. Toward this end, we investigated toward specific built superstructures that could be tailored for the specific urban situation regarding load-bearing structure, integration of greenery and different public functions and amenities, and shading effects. Such ventures have to be well-planned, adapted to local circumstances, and - to be successfully accepted by all involved stakeholders – well worked out together with relevant stakeholders. These are, amongst others, neighbours of adjacent buildings, shopowners, occupants of the public space, politicians, administrative bodies, infrastructure providers, and many more. We used a specific case study location, a street in the densely populated 7th district of Vienna, which in short will require a surface redesign due a subway building site currently being carried out. We Approached the challenges by design (e.g. Fig. 1) and simulation-based evidence evaluation regarding thermal impact on both adjacent dwellings and the street corridor. Moreover, we conducted a set of structured stakeholder interviews with scientists of different disciplines (traffic sciences, infrastructure economics, spatial planning, planning law, sociology, heritage/monuments protection, etc.), local stakeholders (union of local trade companies), and executive/magistrative bodies (local politicians and administrative bodies, firefighters, etc) to find out about the potential of our envisioned structures.

CATE 2024

Evaluating the Efficacy of Daytime Radiative Cooling Assisted Air Conditioning Systems in the Tropics

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Abstract

In tropical urban regions, the urban heat island effect, naturally high temperatures, and climate change have resulted in significant temperature increases over the past few decades. These high temperatures not only worsen outdoor thermal comfort but also raise energy consumption for cooling in buildings. This increased energy use not only generates more heat, intensifying the urban heat island (UHI) effect, but also boosts the demand for cooling energy, which currently accounts for about 50% of total energy consumption. With 40% of the world's population residing in the tropics—a number expected to increase—the need to improve air conditioning system efficiency becomes increasingly urgent. To address this challenge, our study explores the integration of Daytime Radiative Cooling (DRC) with air conditioning systems by applying DRC film to the exterior surface of outdoor units, which facilitates heat ejection through radiation heat transfer. The study, conducted at an outdoor lab in Singapore with the air-conditioning set at 24°C, utilized sensors to monitor key parameters such as surface temperature, indoor airflow temperatures, energy consumption, and weather conditions. Two 72-hour experiments iterations were performed on the same unit: one as a baseline and the other with DRC film, enabling a comparative analysis under consistent environmental conditions. Results showed that DRC film reduced surface temperatures by 1°C and resulted in 3% energy savings. We also discuss the potential for larger energy savings at higher cooling loads.

Enhancing Outdoor Thermal Comfort in Extreme Hot Climates: A Multilayered Approach Using Computational Analysis and On-Site Validation in Kuwait

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Abstract

Enhancing outdoor thermal comfort is crucial to increase cities' liveability, promoting social engagement and encouraging outdoor activities. This study focuses on improving thermal comfort in a large public courtyard redevelopment located in Kuwait's extreme hot climate. The approach integrates on-site measurements with mock-up studies and advanced analytical computational tools to assess effectiveness of multi-layered heat mitigation strategies.

Thermal comfort and microclimate assessments were conducted at the existing site. Utilising weather data, a Universal Thermal Climate Index (UTCI) analysis was carried out using tailored dynamic thermal modelling tools incorporating geometrical and time dependent variables. These analyses evaluate the efficacy of heat mitigation strategies to increase the hours within moderate to no thermal stress across the year. These strategies were verified and corelated with onsite measurements a full scale mock-ups that integrated shade, materials, fans and evaporative cooling strategies. These strategies aligned with the computational tests.

Computational Fluid Dynamics (CFD) analysis was carried out to study the wind effects within the site and to evaluate air movement, in addition, sun-cast analysis was used to optimise shade at critical occupied zones in order to improve the usability of the area. All variables were integrated into a CFD analysis of the combined multilayered strategy at peak time conditions. The study included implementing building shade, extended pavilion structures, local shade structures, strategic landscaping, water features, misting systems, fans and cool pavements. The evaporative cooling effect of water features and misting was accounted for as well as the air movement effect with the use of fans.

The results showed that an improvement by up to 10-16˚C on the equivalent temperature (UTCI) scale and 8-9˚C improvement in dry bulb temperature in localized areas is possible. This represented an extension of acceptable comfort conditions up to 80% of the time annually. This integrative approach describes the potential of enhancing on thermal comfort in extreme hot climates, contributing to the well-being and comfort of individuals in urban retail settings.

Programs and Policies for Comfort, Health and Wellbeing in Buildings

Chair: Jonathan Bean

Green areas of children's parks. The case of the historical town of seville. Guidelines for your design

Martínez-Quesada, M.C. 1 & Navarro Jiménez, F.M. 2

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Abstract

In the digital age, the construction of playgrounds becomes particularly important because of its capacity to influence crucial wood in children's development from the approach and direct understanding of green spaces. Returning prominence to the places where we grow up requires ensuring from childhood the opportunity for real exploration and learning in our own physical space.
The improvement of the ecological, social and aesthetic quality of our urban environments requires understanding nature as a crucial chapter in children's development so that the adult in training can silently incorporate it into their life requirements. The essentiality of geometries and colors in children's spaces must be extended to the forms of nature. The absence of green elements in playgrounds not only affects their aesthetic quality, but also compromises their pedagogical function as a stimulating and safe play place that activates children's ability to explore and ensures their healthy development.
The objective of this research is to improve the visual quality of the playgrounds in the historic centre of Seville and their contribution, including vegetation, both to the integral development of children and to the essential requirements of urban sustainability.
The research is based on three existing manuals for the design of new playgrounds and the recommendations made by neuroarchitecture for the design and configuration of these. Based on this theoretical framework, the children's playgrounds in the historic centre of Seville collected by DERA (Spatial Reference Data for Andalusia) are analysed in detail. Children and their carers have also been interviewed from the survey reference "Analysis of the user profile of playgrounds in Spain".
The conclusions incorporate a design guide of good practice with suggestions for improving the quality of children's play, the beneficial influence on their development and the contribution to the construction of healthier and sustainable urban spaces.

Implementing Occupant-Centric Control Strategies to Improve Occupant Well-Being in Buildings

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Abstract

Within the context of accelerated climate change, optimizing building's energy consumption while maintaining occupant comfort and wellbeing has become a real challenge. Accordingly, Occupant-Centric Control (OCC) has emerged as a promising approach for indoor climate control in which occupants' comfort and preferences are measured from a variety of sensors, control interfaces, questionnaires, or mobile and wearable devices. This data is then used to train models, allowing them to adjust actual context-related conditions and preferences of occupants (O'Brien et al. 2020).
The scope of this paper is to present data-driven strategies used for occupant modeling to foster occupant-centered building operation and design within a multi-domain environmental context. First, a comparative mapping of occupant-related data collection methodologies is presented, categorized into active and passive techniques. Active techniques involve directly querying the occupants through tools, such as comfort questionnaires, feedback applications and wearables. In contrast, passive techniques involve indirectly observing interactions between humans and building components using various sensors. The type and granularity of information, and the strengths and limitations of each method, are discussed in relation to the aspects of indoor environmental quality.
Second, the implementation of OCC strategies within a real office building located in the historical part of Paris is demonstrated. The research presents results from hybrid data collection methodologies that combine active and passive techniques on an office floor occupied by 20 people. The discrepancies between standard comfort set points and preferred comfort set points, as well as the aspects within temperature, acoustics, lighting, indoor air quality, and occupancy that most influence employees' well-being, are discussed.

Collective spaces for seniors. Manual of good practices

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Abstract

The new demographic and social reality of post-industrial society has led to a change in the historical family model, where intergenerational ties ensured the cohesion of the traditional system of help and support. Today, the ageing of the population and the increase in life expectancy are a sign of the risk of physical and cognitive isolation of the so-called elderly, without society appearing to be determined in how to meet its needs by avoiding their exclusion from the common urban space.

In this situation, architecture must take up the challenge of providing solutions for old age, creating spaces adapted to their specific needs with characteristics whose quality affects the health of its users. It is a question of not abandoning the value of belonging linked to the concept of housing, fleeing from institutionalized generalist models in order to generate alternative meeting spaces that respond to their different degrees of vulnerability and dependence.

The initial hypothesis has been to consider the possibility of providing design conditions from healthy parameters for this group, Setting the objective of improving the habitability of community spaces in centres for the elderly to create meeting places that will individually activate their socialization needs.

The WELL certification has been used to this end, and it has been possible to identify parameters with which users can adopt a healthy lifestyle. The analysis of case studies in selected centres was carried out on the basis of a series of climatological, cultural and lifestyle similarities, supplemented by the evaluation of satisfaction surveys conducted in some of them.

Based on the results obtained, a design guide is established with recommendations aimed at improving the quality of life in care centres for older people to create common spaces that facilitate their independence and guarantees a successful, active and healthy ageing.

A comprehensive district scale simulation method to evaluate active and passive building strategies and their influence on outdoor thermal comfort in a hot and humid tropical climate

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Abstract

Outdoor thermal comfort (OTC) is one of the key factors to define the city's livability, which is also known to have direct impacts on people's health and wellbeing. One of the biggest contributing factors to the increase in urban thermal discomfort is the anthropogenic heat emissions from buildings, which is worsened by the over-reliance trend on air-conditioner use in urban environments especially in the tropical region. To counteract this urban heating, extensive research had been done to make modern day buildings more climate responsive, which includes measures on active and passive design strategies. Given the complexity of both urban and climate systems, an integrated modelling approach of building energy and urban microclimate is needed to identify the optimal set of strategies. In this study, the interaction between the building energy balance and the atmospheric canopy layer is modelled using the urban microclimate model, PALM-4U coupled with the mesoscale climate model, WRF, for its boundary conditions, and the building energy model, City Energy Analyst (CEA). To represent the performance of various cooling systems, we modified the existing source code of PALM-4U, to integrate external heat profiles computed by CEA to PALM-4U, and to allow for customized anthropogenic heat (AH) rejection locations. In the end, we implement the proposed workflow to compare the influence of active strategies (i.e., AH released on wall surfaces as a baseline, central cooling systems with standard and high energy efficiency buildings, and district cooling) on the microclimate. The results suggest that the district cooling scenario performs the best in terms of microclimate and OTC for a high-density Central Business District (CBD) area. Minor discrepancies were found between the standard and high building efficiency.

Informing housing planning policy to minimize the need for active cooling in temperate (Cfb) climate

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Abstract

Future climate scenarios indicate an increase in cooling energy demand, further exacerbated by urban heat island (UHI). Most significant increase will likely be the result of mainstreaming active cooling (AC) in housing, including in temperate climate. In Poland, electricity needed for AC operation is produced mostly through burning coal (61%), contributing to the vicious circle of climate change. One of the most effective adaptation measures to reduce the demand for cooling energy in buildings is natural ventilation including nighttime cooling (NC). However, due to the simultaneous occurrence of climate change and UHI, night air temperatures in cities gradually increase. Wrocław, the warmest of large cities in Poland, participates in the EU Cities Mission, a program aiming to facilitate climate neutrality of cities by 2050. Its Municipality is interested in developing policy measures to avoid AC dependency of its housing stock. The aim of the study reported here was to provide the first step in that process. This involved exploring the variation of nighttime air temperatures in direct vicinity of facades, i.e. temperatures most relevant to consider NC potential as an alternative to AC. Outdoor temperature monitoring was conducted between June-September 2024. 32 monitoring locations covered four variables: contrasting risks of UHI, facade orientations, types of external wall and heights above ground level. The results suggest differences that can be linked with each of the four variables examined. Overall, across the 81 days of monitoring in one city, between 2 and 31 tropical nights were observed depending on the sensor location, which is a significant difference. Exploring the impact of variables previously marginalized in the nighttime cooling discourse, such as external wall type, orientation or height above ground level improves understanding of urban microclimate and its impact on NC potential and provides a focus for the related policy interventions.

Integrated assessment of indoor-environmental quality: Is weighting the solution?

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Abstract

Indoor-environmental quality requirements are commonly expressed in separate domains, such as thermal, visual, and acoustic, and indoor air quality. More recently, there have been efforts to address such requirements in a more holistic or integrated manner. Some of these efforts involve multi-criteria scoring systems that apply numeric weights meant to map the relative importance of the items considered in the process onto a single-number total indoor-environmental quality score. This paper offers a number of reflections on the scope and logic of such efforts. To this end, the overall effectiveness of weighting schemes is discussed, addressing the degree to which they disclose the reasoning for the specific selection of variables and the sources of their assigned weights. Moreover, the paper considers alternative means that can serve a similar functionality as the weighting schemes in total indoor-environmental quality assessment methods.

CATE 2024

Study of particulate matter in school classrooms and their relationship with proximity to green areas. Case studies in Santiago de Chile

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Abstract

Indoor air quality (IAQ) in school classrooms is essential for the health, academic performance, and well-being of students. During the colder months, thermal comfort is often prioritized over respiratory comfort, resulting in inadequate ventilation and poor air renewal in classrooms. This study investigates the relationship between nearby green areas and IAQ in classrooms with natural ventilation in Santiago, Chile, focusing on the concentrations of fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}). Four schools located in communes with different degrees of green area coverage were selected, and for each school, two classrooms were monitored for 12 days during the winter of 2024 using sensors. Various variables were measured, primarily $PM_{2.5}$ and PM_{10}, both inside and outside the classrooms. The results revealed that classrooms in communes with greater green area coverage did not consistently show lower concentrations of particulate matter. For example, the school located in the commune with the least green area per inhabitant exhibited lower indoor $PM_{2.5}$ levels than those located in communes with more vegetation, where the presence of deciduous trees and large exposed soil areas did not contribute to reducing suspended particle concentrations. This is due to the lack of foliage on the trees and the limited retention of suspended particles by their missing leaves. The findings suggest that while green areas may influence air quality, other factors, such as the type of vegetation, ventilation habits, and environmental conditions (such as seasonality), also play a crucial role. This study emphasizes the need for further research across different seasons to better understand the impact of vegetation on IAQ, especially when deciduous trees are in full leaf. This knowledge could guide urban planning and the design of green spaces in schools, thereby contributing to the creation of healthier indoor environments for students.

Addressing energy poverty - Empirical evidence on the impact of Passivhaus retrofit in social housing

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Abstract

Evidence has shown that due to financial constraints, occupants of social housing generally use less heating, resulting in indoor environmental conditions that are often colder and more humid, impacting on the health and well-being of residents. Passivhaus design aims to lower heating demand by minimising heat losses, maximising solar gain and ensuring adequate ventilation. This design approach may be a solution to improve the indoor environmental conditions in social housing. This research aims to assess the impact of Passivhaus retrofit (EnerPHit) in social housing on the indoor environment and on the health and well-being of residents. Applying a longitudinal mixed method approach, empirical evidence was gathered from a social housing block of flats, Wilmcote House, located in Portsmouth, UK. This is a typical council house block, build in 1968, containing 107 flats across 11 storeys. Ambient temperature and relative humidity (indoor and outdoor) were recorded before the Passivhaus retrofit in 18 representative flats (2013) and after the retrofit in seven flats (2018). Questionnaires were completed by the residents to understand influencing factors on their health and well-being, concurrently to the monitoring and eight years after the retrofit (2024). Results show that before the retrofit, indoor ambient temperatures were generally low and relative humidity was generally high, impacting the health and well-being of occupants. Using two timeframes (same months and similar outdoor conditions), the post-retrofit results concluded that generally indoor ambient temperature and relative humidity were within the recommended comfort range. The average temperature had increased and relative humidity showing less fluctuation. Residents' feedback reported that air quality was compromised post retrofit. Although this research reviews one social housing block of flats, the results show that Passivhaus retrofit may be one solution to address energy poverty whilst improving the indoor environments.

Urban planning parameters for primary school users. Adaptive design guide in school environment

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Abstract

City is the playing field where everyday life takes place, which must be useful and versatile for life, from connectivity to leisure spaces. But what level of comfort do cities offer to different users?
This question is transferred to primary school environments, where it is common to find congested streets at the entrance and exit of students, narrow sidewalks where they cannot move easily, where each street crossing is dangerous due to the lack of protective infrastructure for pedestrians... These deficiencies are derived from a lack of sensitivity to current needs of students when it comes to urban planning with specific designs and make coexistence difficult, creating stress peaks that put the safety of children, their autonomy, learning and emotional well-being at risk. It is necessary that primary school environments be considered to develop strategies that influence the urban social learning process, involving students, parents and teachers.
The method followed in the research has been based on the analysis of manuals in urban design and school environments; dynamic projects such as the DGT's " School Route Step by Step" whose main objective is to increase the autonomy of children, as well as reduce their dependence on cars to improve children's relationships; scientific studies on urban planning and how it affects children from the point of view of salutogenesis and neuroarchitecture. This has been completed with surveys of children between 6 and 12 years old to find out their perception of place, and of legal guardians and teaching staff, to understand and meet needs of students.
Results and conclusions obtained have been transformed into an adaptive design guide that can be used in the development of specific urban ordinances for areas close to primary schools, which promote safe, accessible, friendly and healthy environments for children and encourage their autonomy and growth.

Harmonization and standardization of data collection techniques across EU labs

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Abstract

Consistent standardization of air quality and pollution data collection techniques is significant for accurately forecasting, analyzing, and assessing air quality and thus, improve the impact on public health. The data analysis experts of the European IPCHEM platform1 have already created standardized templates for differentiating between data owners and data providers. The following issues need to be considered when collecting data: [i] a clear distinction between different air pollution data, i.e. indoor air pollution such as sensor data, health data, biological data, environmental data, human biomonitoring data, survey data, indoor air sampling data, climate data, and toxicological data. [ii] While data collection methods based on surveys are provided by IPCHEM, we argue that sensorics, sampling, and databases need to be regarded as well. Moreover, [iii] the venues of data collection require a clearer distinction among these three categories: [1] residential/homes/households, [2] public buildings indoor, and [3] outdoor public venues. Most prominently, [iv] the data that are measured need to be categorized within a standardized chart. Therefore, EDIAQI project has founded a task force to collaborate beyond EDIAQI's four pilots and four campaigns with all seven IDEAL cluster projects to categorize chemical as well as non-chemical data within an air quality data chart comprising air pollution data definitions within highly structured and less granular categories. First results show that the streamlined definitions make data analysis more concise. Reinforcing the use of this standardized air quality data chart could foster the continuous integration of this scale as new standard within the Horizon Europe Data Management Plan2 thus significantly improve data management within health cluster activities and lead to a clearer and more effective collection, categorization, assessment, and analysis of air quality data

Leveraging community resources to protect the most vulnerable: A case study on heat mitigation in India's informal settlements

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Abstract

As global temperatures rise, the nearly 2.6 billion people who live without air conditioning in hot climates are becoming increasingly vulnerable to heat stress (Mastrucci, et al., 2019). There is a great need for technical solutions that deliver comfort in extreme heat. Fair Conditioning works with vulnerable communities in India to co-create solutions to reduce solar heat gain in local buildings. They have developed innovative techniques to cool informal dwellings by deploying a spectrum of passive design techniques. These include: louvered and sliding panels that act as radiant barriers; under-the-roof insulating panels made of Alufoil or wood wool made from local, sustainable organic materials; rooftop thermal storage created from waste materials (i.e., plastic bottles diverted from the local landfill); and rooftop gardens that offer cooling through thermal mass, shading, and evaporative cooling. Through a participatory design process, materials and prototype designs are evaluated and refined. Field testing of the solutions developed has been conducted in a small number of homes. Sensors installed to monitor indoor temperatures pre- and post-installation suggest the solutions decrease indoor temperatures by 2-4°C and considerably improve occupants' quality of life. Fair Conditioning is collaborating with local producers to develop a robust supply of sustainable materials and with women's groups to establish a thermal retrofitting business model. Fair Conditioning's approach to creating solutions to mitigate extreme heat serves as a model for appropriate technological and economic development that can and should be replicated in other heat-affected communities around the world.

CATE
2024

Evaluating the accuracy of the thermal comfort model in predicting occupant sensation in hot climate air-conditioned office buildings

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Abstract

Thermal comfort prediction models have been criticised for failing to accurately capture occupants' actual thermal sensations, which can result in discomfort and increased energy usage for cooling in buildings, particularly in hot climates. This study evaluates the accuracy of the Predicted Mean Vote (PMV) model in predicting thermal comfort levels in air-conditioned office buildings located in a hot tropical climate. Data were collected from three office buildings (n = 30) in Abuja, Nigeria, where indoor environmental measurements were taken, and occupants provided subjective responses using thermal sensation votes (TSV). The results showed a discrepancy between the PMV model's predictions, and the actual thermal sensations reported by occupants. While the PMV predicted a near-neutral thermal environment with an average PMV of 0.44 and 80% of participants expected to feel neutral, 34.5% reported feeling slightly cool, and only 27.6% indicated neutral feelings, with an average TSV of -0.10. These findings are in line with recent previous studies that suggest the PMV model may not fully account for the thermal comfort needs of occupants in hot climates, indicating the need for comfort models to consider contextual factors. Further research is recommended to explore the contextual factors influencing thermal perception and to refine predictive models for improved accuracy in tropical regions.

Early stage ventilative cooling methods in building design: A review and a proposed simplified methodology for use in practice

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Abstract

Designing for net zero energy consumption and comfortable indoor environments at extreme temperatures for both new and retrofit buildings presents a challenge for building designers globally. The latest research has shown that at early stages of building design, simplified ventilative cooling guidelines can assist the building design practitioners in making better design decisions to incorporate ventilative cooling for avoiding overheating. This paper presents a brief review of ventilative cooling methods and tools that can be incorporated at various stages of the building design process. A criteria for assessing the suitability of these methods at various stages of building design is also proposed. A simple model has been developed for an office room located in Lahore, Pakistan and a comparison of three different ventilative cooling methods has been made using three different tools (Climate Consultant, Ventilative Cooling Potential Method (2018) and Integrated Environmental Solutions, 2024). The results show that at early stages of building design, dynamic thermal simulations are not necessarily required. For summer months in Lahore (May to September), natural ventilative cooling only does not provide optimum thermal comfort as determined by all tools. Climate Consultant presents guidance only about the strategies that can be used for any non-domestic building type in Lahore. Ventilative Cooling Potential Method (2018) shows the use of evaporative cooling in the months of July and August. Finally, detailed level dynamic thermal simulations shows that the residual discomfort hours shown by this tool can be reduced by applying air conditioning. Future research can build on the work from this study to present simplified design guidance for ventilative cooling technologies using sensitivity analysis of different room parameters and climates.

Evaluating Indoor Environmental Quality, Health and Wellbeing in Campus Buildings of Different Building Vintages: Implications for Energy Retrofit Decisions

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Abstract

As universities strive to meet aggressive greenhouse gas emission reduction targets, the trade-off between energy use intensity (EUI), and indoor environmental quality (IEQ), comfort, health and wellbeing becomes more critical. Meanwhile, lecture halls remain under-researched regarding IEQ, health and wellbeing, creating a knowledge gap for universities aiming to balance energy efficiency with occupant experience. This study, conducted as part of the ongoing Campus Wellbeing Project at the University of Toronto, investigates differences in IEQ satisfaction, comfort, and self-reported health and wellbeing of students in learning environments located in buildings of different vintages, and their implications for energy retrofits.

Survey data was collected from undergraduate students (N=170) having classes in three lecture halls at the University of Toronto St. George campus in Winter 2024. These lecture halls, built in 1961, 2004, and 2018, offer a comparative analysis. All are mechanically ventilated with no window access. The survey questions relate to satisfaction with IEQ factors (indoor air quality, thermal comfort, lighting and acoustics) and overall comfort (very dissatisfied to very satisfied) as well as whether health and wellbeing was positively impacted by the classroom environment (strongly disagree to strongly agree), both on a 7-point Likert scale. Data analysis involved boxplots to visualize satisfaction scores, the Shapiro-Wilk test for normality, the Wilcoxon Rank-Sum Test to compare satisfaction scores across buildings and Cliff's Delta to assess effect sizes. Additionally, Spearman rank correlation test was used to explore associations between IEQ factors, overall comfort, health, and wellbeing. EUI benchmarking against other campus buildings in similar climates provided context for the energy performance of each building.

Study results indicated that while the 2018 building outperformed the others in IEQ satisfaction, the 2004 building had the lowest satisfaction scores across most parameters, with an EUI more than double that of the both the 1961 and 2018 buildings. This suggests a non-linear relationship between building vintage and occupant satisfaction, comfort, health and wellbeing. Instead of prioritizing the oldest buildings for deep energy retrofits, retrofits should be prioritized based on buildings which see significant occupant dissatisfaction and high EUIs, which may be more contemporary buildings depending on their design and operation. These insights suggest that retrofit priorities should account for both EUI, IEQ satisfaction, health and wellbeing, not just building age, to help create campus environments that support climate goals and promote wellbeing.

Contemplated Changes to the Adaptive Thermal Comfort part of standard EN 16798-1

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Abstract

A group of international IEQ and thermal comfort specialists is rewriting the existing European indoor climate standard EN 16798-1 incl. the adaptive thermal comfort part. The standard, including the Annex that describes the adaptive comfort criteria, will be improved where necessary to make sure it is more in line with the latest insights and results from recent scientific (field) studies.

In this paper we explain what the major changes are that are contemplated now the standard will be updated. One idea is to review the definitions and the titles of the building categories. Possibly, the term 'freerunning' could be reintroduced in that context. Another idea is to introduce a flowchart that helps decision makers to more easily decide whether a building fits the 'without' or the 'with' active cooling system category. Special attention could be given in that context to hybrid cooling solutions, think e.g. of buildings with Thermally Activated Building Systems (TABS).

There is a mathematical inaccuracy in the existing formula for the running mean outdoor temperature; this should be solved too in the next version of the standard.

Interpretation of the temperature bandwiths presented in the standard also could be improved. Additionally it might make sense to include specific temperature requirements for the shoulder seasons. Furthermore, it might make sense to be more explicit about the respective negative and positive effects (in summer) of extreme high humidity levels or above average air speeds indoors.

Effect of thermal environment on user comfort in UK university buildings with multinational occupancy

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Abstract

Due to the significant increase in the number of international students attending UK universities in recent years, educational buildings have become a good example of buildings with multinational occupancy. While this situation has allowed people from different nationalities and cultures to come together, it has also caused different problems to arise. One of the most important of these problems is providing equal comfort conditions to occupants. Comfort is important because the environmental conditions, especially in lecture theatres, can affect the health and productivity of occupants. However, occupants from different nationalities may evaluate the thermal conditions of their environment differently due to their past experiences. This it makes it difficult to provide equally comfortable conditions to all occupants. For this reason, this study compared the comfort conditions of home students and international students in lecture theatres at the University of Liverpool in England. Participants were asked to complete an online survey designed to investigate factors affecting their thermal comfort and perception of environmental conditions in the space. A total of 340 students participated in the study. Simultaneously, temperature and relative humidity levels in the study area were monitored using data loggers. Based on non-parametric statistical analysis, it was observed that the nationality of the participants affected their thermal sensations, preferences and clothing level. While the findings of this study show the current state of lecture theatre heating and cooling set point temperatures, they also reveal how perceptions of thermal comfort are affected by longer-term experience of climate, with important lessons for how to manage interior environments as the climate changes over the coming years.

Thermal Comfort Models and Metrices, and Resilience

Chair: Federico Tartarini

CATE 2024

Investigating the effect of bedroom temperatures on thermal comfort and sleep quality in natural settings

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Abstract

Adequate sleep is crucial to human health and well-being and elevated night-time temperatures can degrade sleep quality. European countries with temperate climates use temperature thresholds between 25°C and 28°C to identify homes that are overheated. The current UK bedroom threshold temperature of 26°C is based on one small study which is now over 45 years old.; a new bedroom overheating criterion has recently been proposed.

Internationally, there have been very few studies of bedroom temperatures and their influence on thermal comfort and sleep quality for people sleeping in their natural environment. Early results from one such study, the Homes Heat Health project are reported. Data were collected during the summer of 2023 from 25 participants living in apartments (flats) in East London. The participants were healthy with no pre-existing medical conditions that would affect their sleep. A survey recorded the geometry and thermal characteristics of bedrooms, sensors recorded bedroom temperatures and humidity, actigraphy was used to measure night-time sleep patterns, and a phone app captured participants' nightly comfort and sleep quality.

The nighttime bedroom temperatures and self-reports of thermal comfort and sleep quality during a week of hot weather were compared with reports made during a week of typical summer weather. Mean and maximum nighttime bedroom temperatures were significantly warmer during the hot week ($p<0.001$). Compared to the typical week, there was a significant reduction in reported sleep quality ($p<0.05$) and thermal comfort ($p<0.001$) and an increase in sleep disturbance ($p< 0.001$).

Adaptive Model of Thermal Comfort for Heritage Hotels in warm humid climate of India

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Abstract

India's landscape has a diverse tapestry of geographical characteristics, each contributing to the nation's cultural legacy and natural richness. Cultural heritage sites worldwide are at great risk due to climate change, and India is no exception. India's rich cultural history is already being adversely affected by the consequences of climate change, including rising sea levels, severe weather events, and alterations in temperature and rainfall patterns. To mitigate climate change and its impact many sustainable alternatives like conserving heritage buildings by putting them to new use are being practiced and advocated in India.

This study concentrates on evaluating thermal comfort in heritage buildings put to new use especially as heritage hotels in the warm humid climate of India's eastern region. The main research question of the study is to examine whether adapted heritage buildings can provide both cultural values as well as thermal comfort solutions.

This paper showcases field study findings of occupant thermal comfort for a mixed mode heritage building located in the warm humid climate of Orissa in India. A total of 226 respondents were examined spread over four seasons. The transverse survey data was collected through yearlong monitoring of environmental parameters along with occupant survey through spot measurements and questionnaires.

In India, there is a paucity of study about thermal comfort in heritage structures, rendering this study a pioneering investigation for the heritage hotel typology worldwide. The research demonstrates the level of thermal comfort attained in a modified heritage hotel, using environmentally adaptable design elements for effective thermal adaptation. The research emphasizes significant findings concerning occupant comfort and environmental conditions in the heritage hotel. The naturally ventilated corridors consistently exhibited lower temperatures than the actively cooled public areas, indicating that natural ventilation is an exceptionally effective cooling method. These realizations highlight the potentially beneficial role that natural ventilation plays in enhancing occupant comfort, particularly in climates that are warm and humid.

From Intuition to Calculation: What drives Occupant's Thermal Comfort Decisions?

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Abstract

Thermal comfort in (indoor) environments is a multi-faceted phenomenon influenced by technological, cultural, and individual factors. While technically considered as matter of achieving/maintaining specific temperature- and humidity levels, as well as air quality standards, our research proposes a broader, ethnographic approach to **understand thermal comfort as a socially constructed and dynamic practice.** Drawing on key theoretical insights from Madsen and Gram-Hanssen (2017) and Shove et al. (2008), we explore how comfort is not merely a physical state, but a socially shared understanding embedded in everyday practices and interactions with the built environment and technological infrastructures. Recent research reckoned that the **dimension of knowledge and skills** people use for everyday heating and cooling practices – specifically, the roles of embodied knowledge, experience-based know-how, and their intersections – are still not comprehensively explored (Martin & Larsen, 2024). Further, emerging technologies like smart thermostats and IoT-approaches are introducing new dimensions to this discourse: The implementation of "intelligent" algorithms and automated decision-making (Velkova et al. 2022) raises important questions about how such developments shape our perception and knowledge of thermal comfort and how they affect our daily routines. To address this, we propose utilizing a bundle of ethnographic methods, including qualitative interviews, mental mappings, and video ethnography (Pink et al. 2015), to capture **the nuanced and often invisible elements of knowledge** that may contribute to – or even contradict against – thermal comfort. Our aim is to investigate the various forms of knowledge about heating, cooling, and ventilation, and to trace the origins of learned behavior. We want to find out what people know about thermal comfort and where they derive their knowledge from (e.g. advice literature, "gut feeling", apps, experience, common sense, scientific knowledge, "traditional" and/or social media…). Our empirical findings can thus help developing advising strategies that prepare individuals to adapt to both, changing climates and changing technologies.
This paper provides the key concepts and theoretical grounding of a proposed method tool box. This toolbox is currently under testing in the academic framework of the TU Wien via a course bundle for graduate students, in which about 30 ethnographies of thermal comfort based on the aforementioned theoretical background are currently under creation.

A preliminary review of boundary conditions of thermal indicators with focus on occupant resilience

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Abstract

Climate change has noticeably intensified extreme weather events, such as heat waves. Individuals residing in indoor, semi-outdoor or outdoor spaces increasingly encounter challenges associated with the surrounding thermal environment. Consequently, there is a need for evaluating occupant resilience, the ability of occupants to cope with external disturbances such as extreme weather events.

Thermal indicators play an important role in evaluating occupant resilience associated with the surrounding environment. The present study reviewed thermal indicators in international standards and scientific literature. The primary objective of this study was to summarize the boundary conditions of thermal indicators focusing on heat stress, limits of their applicability, and classifications.

The findings from this paper preliminarily suggested roles of thermal indicators in occupant resilience classified in five stages, namely two neutral conditions (before and after stress), thermal stress development, constant thermal stress and recovery from thermal stress. For evaluating occupant resilience, the Predicted Mean Vote (PMV) and the Adaptive Model may be employed to assess occupant thermal conditions before and after exposure to thermal stress. Wet Bulb Globe Temperature (WBGT), Standard Effective Temperature (SET) and Physiological Equivalent Temperature (PET) may be effective for issuing risk alerts with limited thermal stress of occupants. The Predicted Heat Strain (PHS) model may be used for detailed analysis when constant heat stress continues. The Universal Thermal Climate Index (UTCI) may be suited for analyzing thermal stress for all stages. The findings serve as a preliminary step for future study of developing an occupant resilience evaluation framework and an integrated thermal indicator.

Habits and thermal comfort in Brazilian houses: differences and similarities identified through field studies conducted in the country's Northeast and South regions

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Abstract

Worldwide, field measures are generally conducted in commercial or educational buildings where people spend long periods, and it is easier to reach a significant sample for statistical purposes. As a result, little is known about thermal comfort in the residential sector, where the main limitations are the short investigation period and the small samples. The main objective of this paper is to contribute to the discussion of this gap by assessing the main findings from two Brazilian datasets. Previous studies have shown a predisposition for natural ventilation use even during the hottest periods of the year. However, does this predisposition occur uniformly, considering the Brazilian territorial extension and climate diversity? How do the occupants respond to the most extreme temperature ranges? The datasets were recorded in Brazil's south (Florianópolis) and northeast (São Luís). Different climatic realities characterise both cities. Florianópolis has well-defined seasons in a subtropical and humid climate, whereas São Luís is hot and humid throughout the year. Air temperature and humidity were recorded using portable sensors left in the residences' living rooms and bedrooms, while thermal comfort questionnaires were sent via smartphone. The main similarity observed between samples was the preponderance of natural ventilation, even under temperatures up to 32 °C, despite the widespread availability of air conditioning units. In contrast, the main difference was in thermal sensation: households in Florianópolis showed greater discomfort than in São Luís when temperatures exceeded 27 °C. These results can be explained by households' low expectations, adaptive behaviours and the resilience observed in populations from regions with stable temperatures throughout the year. The conclusions drawn in this paper are valuable in shaping a national normative scope for thermal comfort and supporting a national framework for resilient strategies based on households' thermal adaptations in Brazilian residential buildings.

Understanding the effects of short-lived dynamic environmental exposures on occupant comfort in offices

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Abstract

Recent research in occupant comfort and satisfaction increasingly considers the dynamics of the indoor environment. Experimental studies have shown the effects of physiological and psychological adaptation to dynamic indoor environments due to changes in short-lived exposures. However, studying the effect of dynamic indoor environments on occupant comfort in field studies may further the understanding of occupant behavior and comfort assessment in buildings. This exploratory study examines the effect of short-lived dynamic environmental exposures on occupant comfort and satisfaction. The term ‘short-lived exposures’ defines events when participants actively perceive a change in their environmental conditions for less than 5 minutes. This perception period is different than the actual duration for which the changed environmental conditions persist.

Field studies were conducted in two office spaces with a total of 10 participants located in Louvain-le-Neuve, Belgium, over two weeks during spring 2024. Objective data was collected through measurements of indoor environmental parameters and the immediate environment around participants. Subjective feedback regarding comfort, satisfaction, perceived changes in the environmental conditions that occur naturally in offices, and affect was collected through short questionnaires administered multiple times a day. At the end of each week, semi-structured interviews were conducted to develop a deeper understanding of participants' reported events and associated environmental assessments.

Results obtained from quantitative data analysis were interpreted alongside qualitative insights. Out of the 131 reported change events, majority were categorized by participants as mono-sensory stimuli, with maximum events pertaining to the acoustic domain. Nearly 14% of the reported change events were categorized by participants as multi-sensory. Further, interview transcripts were analyzed to identify themes in responses.

These results prompt discussions regarding the interpretation of terminologies and reporting behaviors of participants which are relevant in multi-domain comfort studies. However, the small sample size is a limitation of the study. Future research could focus on larger-scale field studies to investigate the impact of dynamic indoor environments on occupant behavior and comfort assessment in diverse settings.

The potential of repeated thermal relief for evoking pleasure and increasing human resilience

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Abstract

Introduction: The distinction between distress and eustress is known in occupational medicine and beyond for decades. However, when considering physical conditions at workplaces, a strong focus on the avoidance of distress and the provision of stable conditions within small exposure ranges can be observed both in science and practice. At the same time, few studies suggest benefits of dynamic, broader ranged conditions for increasing human resilience and energy efficiency relevant for combatting climate change. Nevertheless, knowledge regarding human reactions to repeated dynamic conditions is still scarce. Hence, the objective of this study is to gain insights into the effect of sequences with thermal stress and relief on thermal sensation, pleasure and physiological reactions.

Methods: Participants (N(Total)=60, N(Female)=31) in two age groups (N(<32 years)=33, N(>50 years)=27) participated in one three-hour session in a controlled laboratory setting and experienced each a repeated measures design with 8 sequences of thermal stress and relief. Each sequence began with 10 minutes of thermal stress (room temperature 30°C, long trousers and shirts, air velocity < 0.05 m/s) followed by 4.5 minutes of relief (same temperature/clothing, air velocity approx. 0.3 m/s). Subjective (perception) and objective (physiological) reactions were collected throughout.

Results: Thermal sensation followed predictions and significantly changed from slightly warm to neutral between stress and relief (Z=16.5, p<.001, d=0.96). Simultaneously, thermal pleasure increased (Z=10.4, p<.001, d=0.50). However, physiological reactions only partly support psychological ones.

Discussion and limitations: On the one hand, results give important insights into positive effects of dynamic thermal conditions and contribute to the discussion on factors supporting human resilience. On the other hand, due to the artificiality of the thermal sequence and small sample size, practical limitations exist in relation to the generalizability of results and direct practical application.

Spatial Thermal Autonomy (sTA): A New Metric for Enhancing Building Design Towards Comfort, Heat Resilience and Energy Autonomy

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Abstract

Achieving thermal comfort in buildings while maintaining energy efficiency is a critical challenge in architecture and engineering design and operation. Traditional thermal comfort metrics used in the early stages of design tend to neglect two key aspects: spatial variability of thermal conditions within buildings and the promotion of passive design strategies over active conditioning systems. This oversight leads to localized discomfort, excessive energy use, and increased vulnerability to overheating. To address these issues, we propose a novel metric called spatial Thermal Autonomy (sTA). The primary advantage of sTA is its ability to capture spatial variability in thermal conditions, offering a more comprehensive view of comfort across different building zones. Additionally, sTA supports passive design by quantifying a building's capacity to maintain comfort without active energy use. We performed a simulation case study evaluating sTA for different thermal zone sizes, passive design levels, and climate scenarios. Our findings suggest that buildings with high spatial thermal autonomy tend to use less energy, demonstrate greater thermal resilience during extreme weather or power outages, and experience fewer local discomfort problems. Optimizing building designs for spatial Thermal Autonomy encourages passive design solutions in key decisions related to building form, envelope, conditioning strategies, and HVAC system design. In buildings with reduced heating and cooling loads, this approach supports the increased adoption of local low-energy personal comfort systems, such as fans or local heating solutions, and can lead to more adaptive, resilient, and comfortable indoor environments in a changing climate.

An exploration of future-climate resilience of an Eco-Pod in South Australia

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Abstract

Recent research shows that extreme weather events may increase not only in number, but also in intensity and overall duration worldwide. Australia is reported as one of the world's regions that is particularly susceptible to heat waves and drought conditions in the future. Understanding future-climate resilience of buildings in this context becomes essential to maximize both occupant comfort and building energy efficiency. "Eco-pods" – an ecologically sensitive small structure for mid-to long-term residential use, similar to the concept of "tiny homes" – have been studied in the last decades as affordable options for a broad range of demands, including for emergency accommodation. Nevertheless, the impact of design strategies for these types of buildings in the context of future climates, as well as considering future extreme weather, remains under-researched in current literature. This study presents a preliminary exploration of the thermal performance of an Eco-pod designed for the South Australian context. Using building performance simulations, the Eco-pod's model was used to predict the dwelling's performance for 2050, 2070 and 2090 climate data considering three future greenhouse gas emission scenarios. Results indicate that passive design strategies such as thermal mass, low air infiltration rates and optimal window size and positioning should remain essential to increase the future-climate resilience for this design in this location. The best combination of these strategies resulted in a design with 75.2% of hours in a year within the comfort range in 2090 in the most extreme future climate scenario. Although commonly disregarded in current Eco-pods and tiny house developments, these elements are necessary to maintain comfort without heavy reliance on heating and cooling in future climates. Findings from the study also provide further insights on affordability and life cycle cost considerations for future developments of Eco-pods in Australia and worldwide.

Proactive and Reactive Thermal Comfort Behaviors

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Abstract

The expansion of renewable electricity generation, growing demands due to electrification, greater prevalence of working from home, and increasing frequency and severity of extreme weather events, will place new demands on the electric supply and distribution grid. Broader adoption of demand response programs (DRPs) for the residential sector may help meet these challenges; however, experience shows that occupant overrides in DRPs compromises their effectiveness. There is a lack of formal understanding of how discomfort, routines, and other motivations affect DRP overrides and other related human building interactions (HBI). This paper reports preliminary findings from a study of 20 households in Colorado and Massachusetts, US over three months. Participants responded to ecological momentary assessments (EMA) triggered by thermostat interactions and at random times throughout the day. EMAs included Likert-scale questions of thermal preference, preference intensity, and changes to 7 different activity types that could affect thermal comfort, and an opened ended question about motivations of such actions. Twelve tags were developed to categorize motivation responses and analyzed statistically to identify associations between motivations, preferences, and HBI actions. Reactions to changes in the thermal environment were the most frequently observed motivation (118 of 220 responses). On the other hand, almost half (47%) responses were at least partially motivated by non-thermal factors, suggesting limited utility for occupant behavior models founded solely on thermal comfort. Changes in activity level and clothing were less likely to be reported when EMAs were triggered by thermostat interactions, while fan interactions were more likely. Windows, shades, and portable heater interactions had no significant dependence on how the EMA was triggered. These results suggest that better understanding of motivations for HBI may improve effectiveness of demand response programs.

The complex effect of vegetation on human thermal perception in warm conditions: Real or imaginary?

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Abstract

Studies show beneficial effects of vegetation for humans, such as improved air quality, heat moderation and stress reduction. It is also assumed, so far with little robust evidence, that in addition to its well-established physiological effect, vegetation also has a psychological effect on thermal stress: Individuals in warm environments feel cooler in the presence of extensive vegetation than in a similar setting *with an identical physiological equivalent temperature* (PET) but less vegetation.
Our study examined 322 subjects engaged in sedentary activity in diverse outdoor settings with varying vegetation levels under very warm conditions. Plant cover exposure was quantified using fish-eye images from participants' viewpoints. PET was calculated using adjacent micrometeorological measurements. Metabolic indicators (pulse rate, skin temperature, and electrodermal activity - EDA) were recorded using Empatica E4 wristbands to establish thermal stress. Subjective thermal sensation, preference, and comfort votes were obtained through questionnaires.
We provide, for the first time, empirical evidence that quantifies the psychological effect of vegetation cover on thermal votes. The mere presence of vegetation in a person's field of view (FOV) had a positive effect when average PET exceeded ~32°C. Thermal comfort improved with increasing Vegetation View Index (VVI), and preference votes indicated greater heat tolerance. These subjective responses correlated with measurable, significant differences in participants' physiological stress levels, as assessed by skin conductance level. The beneficial effect of vegetation on thermal stress increased non-linearly with vegetation cover, particularly from a median coverage of ~11%.

Urban Heat Island and Outdoor Comfort

Chair: Marcel Schweiker

Evaluating Pedestrian Thermal Comfort in an Educational Facility Located in a Hot Arid Climate

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Abstract

Numerous universities have been built on massive grounds leading to the dependence on motorized transportation, especially in hot arid climates. Reductions on this dependence could be made by the provision of walkable corridors and walkways. One crucial factor influencing the walkability of corridors is outdoor thermal comfort which is recognized for impacting pedestrians' perceptions of outdoor environments. This is particularly noticeable in hot arid climates. Therefore, the current study aims to examine pedestrians' thermal comfort during their walking activity in a selected route located within a university campus in a hot arid climate to identify the relationship between thermal sensation and various meteorological parameters. A group of participants were guided across a structured walk through a selected route where objective and subjective data were measured. Measurements were used to propose a model through multiple linear regression between thermal sensation vote (TSV) and several climatic variables. The proposed model resulted with an R^2 value of 0.46 and revealed that natural wet-bulb temperature and air temperature had a significant influence on TSV. Pearson correlation between the actual and predicted TSV revealed a relatively strong relationship resulting with a value of 0.68. Findings of this study provide guidance for the design and enhancement of thermal environments at a pedestrian level by presenting a starting point for the determination of suitable temperatures required to design thermally comfortable outdoor spaces and the possibility of reducing air temperatures by the adoption of natural and architectural elements as revealed by the assessment conducted on the thermal environment.

The Implications of Heatwaves for the Built Environment in India

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Abstract

As climate change intensifies, the frequency, intensity, and severity of heatwaves and Urban Heat Island (UHI) effects are escalating, posing significant challenges to urban areas worldwide. Urbanisation plays a pivotal role in amplifying UHI and heatwaves, accounting for a substantial portion of their overall impact in urban locales. Tropical regions have witnessed a substantial increase in heat extremes, surpassing historical variability thresholds. It has been suggested that at 1.5°C warming conditions, double the existing number of megacities will experience heat stress, exposing over 350 million more people to extreme heat by 2050. Various studies have demonstrated that extreme heat is more fatal than any other extreme weather event globally each year. Elevated urban temperatures can result in increased stress on urban services such as electricity and water availability. This, coupled with diminished air quality, reduces city residents' overall health and well-being. The combined effects of UHI and heatwaves (HW) increase energy cooling loads to provide thermal comfort and exacerbate outdoor heat stress, thereby slowing down the de-carbonisation efforts. It has been reported that UHI and HW phenomena may cause an increase in cooling energy use of between 10–16% in areas where air conditioner usage is prevalent. Climate resilience has become a paramount objective in building design, underscoring the significance of sustainable adaptation strategies in alleviating the adverse effects of extreme weather events. It is crucial to steer clear of adaptation strategies that inadvertently heighten energy consumption or worsen vulnerabilities among specific populations. This paper addresses the implications of extreme heat events on the built environment through a brief overview of HW circumstances in India, a discussion of possible adaptation and retrofit measures to mitigate the impacts of UHI and HW, and a specific case study of the impact of HW on a building's cooling energy requirements.

Assessing Thermal Comfort in San Julian Square, Seville for the Development of Mitigation Plans

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Abstract

Research on urban thermal comfort is crucial due to rising temperatures and the urban heat island effect. This study evaluates factors influencing thermal comfort in Seville’s historic San Julian square, a typical small square with limited greenery and no water features. Despite its significance, concerns about the thermal comfort of residents and visitors persist, especially in Seville's warm Mediterranean climate.

Using a combination of field measurements, simulations, and data analysis, we assess parameters like air temperature, wind speed, and relative humidity. Simulations using ENVI-met software (v5.1.1) help evaluate thermal conditions over time.
We propose strategies such as shade structures, added greenery, and optimized surface materials to reduce heat stress. Our study offers practical solutions for improving thermal comfort in urban public spaces.

Limitations and opportunities of data transformation strategies for generating analytical models from BIM

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Abstract

The rapid growth of urbanisation has significantly increased cities' environmental impact. International calls for a paradigm shift in urban design emphasise the need for sustainable and climate-responsive strategies. This paper explores the potential of Building Information Modelling (BIM) methodology in facilitating such a shift, particularly through its role in developing innovative simulation-assisted design methods. A critical area of development is improving semantic interoperability among modelling and simulation tools within the BIM environment through standardised data exchange formats and methods. Interoperability issues are especially problematic when integrating advanced analytical models (such as those used for microclimate analysis) into BIM design workflows. While numerous studies have reviewed interoperability strategies concerning urban and architectural design and simulation tools, a significant research gap remains in addressing advanced data exchange methods between BIM and analytical models to support urban microclimate impact assessments. To address this gap, this paper conducts a systematic review of the latest Industry Foundation Classes (IFC) transformation strategies for generating analytical models from BIM data and proposes a novel unexplored pathway via Revit APIs. As an initial stage of this emerging workflow, we implement and test the Pollination plugin for Revit as a data transformation strategy. This approach aims to assess the microclimate impact of facade design by integrating the widely used BIM tool Revit with highly validated simulation engines within the Grasshopper environment, specifically employing Ladybug and Honeybee components for microclimate impact assessment. Our case study demonstrates that this method can effectively generate accurate analytical models suitable for microclimate impact assessment in retrofitting projects. However, challenges in generating meshes and sensor grids indicate the need to refine the emerging workflow further in future work. Addressing these challenges is crucial for advancing BIM's practical application and realising its full potential in promoting net-zero targets in urban and building design practices.

Model validation of one-way coupling between WRF and PALM-4U model to evaluate outdoor thermal comfort in tropical region

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Abstract

We validate the microclimate model, Parallelized Large Eddy Simulation Model for Urban climate (PALM-4U), against field measurement data. We conduct realistic urban microclimate simulations in a high-density tropical region, specifically in Singapore. The simulation is done using PALM-4U model, coupled with Weather Research and Forecasting (WRF) multilayer urban canopy model (MLUCM). The coupling between WRF mesoscale model and PALM-4U is done via one-way forcing from the WRF simulation output into the initial and boundary conditions of PALM-4U model. Various urban elements are taken into consideration in PALM-4U simulation, including building data, land and surface types, trees as well as the anthropogenic heat generated from buildings, to represent a more accurate and realistic urban setup. It is crucial to validate and calibrate microclimate models using observation data. This helps to ensure that the model's predictions are aligned with the actual observed conditions, and to allow for further evaluations, such as for the what-if-scenario comparison. In this paper, we conduct two validation case studies, while one study focuses on the densely built-up area in the downtown (CBD), the other focuses on urban park and vegetation on Bishan-Ang Mo Kio (BAMK) Park. The result suggests that the coupling method can predict well the microclimate in the tropical region both for urban and large vegetated zone within an urbanised area, indicated by the model's ability to mimic the diurnal cycle produced by the observation data with relatively low RMSE.

Singapore’s Digital Urban Climate Twin: an analysis of heat mitigation measures from island to neighborhood scale

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Abstract

The Urban Heat Island (UHI) effect intensifies thermal stress in cities, impacting population health, energy consumption, and overall liveability. Climate modelling is crucial for assessing and optimizing heat mitigation measures. The complexity of the UHI, however, requires an integrated approach that captures the spatio-temporal complexities of different urban elements, such as land use, buildings, and other anthropogenic heat sources. In this study, we utilize a Digital Urban Climate Twin (DUCT) that incorporates city-specific data within a mesoscale climate model for the city of Singapore, enabling a detailed analysis of how changes to various urban factors influence air temperatures. Specifically, we test three mitigation measures: transitioning fully to electric vehicles (EVs), enhancing building air-conditioning efficiency, and increasing urban vegetation. Results reveal distinct spatial patterns and time-of-day impacts from the three approaches. A 100% adoption of EVs leads to a notable reduction in nighttime air temperatures, with peak cooling effects observed during morning traffic rush hours, especially towards the central business district regions with a high density of traffic networks. Improvements in building air-conditioning efficiency and set-point temperatures show minor nighttime cooling effects but demonstrate a reduction in midday temperatures. Additionally, the study highlights the role of urban vegetation in moderating diurnal surface heat fluxes, underscoring its potential to mitigate urban heat. These comparative studies demonstrate the use of the DUCT as a tool to guide policy implementation through simulations, enabling the development of more targeted heat mitigation strategies across various spatial scales.

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Multidomain typology of environmentally vulnerable neighbourhoods for enhanced mitigation strategies

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Abstract

Cities are facing unprecedented challenges due to continuous growth, creating a multitude of environmental issues including urban overheating, daylight deficiency, noise, and air pollution. This requires an integrated approach to research and implementation of mitigation strategies, aiming at improving overall environmental quality rather than limiting efforts to a single domain. This study aims to develop a method for classifying a city into distinct and identifiable types based on their multidomain environmental characteristics and to examine the environmental vulnerability of these neighbourhood types. The study adopted a data-driven approach for classifying neighbourhoods in *Bern*, *Switzerland*, based on parameters describing neighbourhood morphology, land cover, and road network. The K-means algorithm was used to cluster the 700 neighbourhood units. Outdoor environmental quality indicators from open databases and remote sensing were used to assess the environmental conditions of these neighbourhoods, including *land surface temperature*, *direct solar radiation*, *air pollutant concentration (PM2.5, PM10, NO2)* and *traffic noise*. A total of 10 neighbourhood types emerged from the analysis. They exhibit distinctive environmental conditions in four domains, including thermal condition, daylight, air, and acoustic quality. Environmentally vulnerable neighbourhood types are identified, including those with high density (building coverage = 30±10%), dense primary road networks, or the presence of highways. The implementation of urban heat island mitigation strategies should be considered within the broader multidomain environmental context to maximize co-benefits and minimize trade-offs. Context-specific measures are needed for the identified types of neighbourhoods in the current study to promote overall environmental quality and comfort, especially during extreme weather events. Socio-economic and health vulnerability can be integrated with the multidomain neighbourhood typology in the future to inform policymaking for shaping more resilient cities.

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Methodological Perspectives to Evaluate Combined Indoor and Outdoor Thermal Comfort and Improvement Measures in Vienna's Urban Heat Islands

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Abstract

The progression of climate change and the resulting amplification of the Urban Heat Island (UHI) effect poses significant challenges on metropolitan areas like Vienna. Past research has often separately examined thermal comfort on indoor and outdoor spaces and the increased energy demand for cooling caused by UHIs. Since cities and their heat and energy dynamics are interconnected entities, where buildings and open spaces are inseparable, the occupant’s wellbeing is not only dependent on indoor spaces but also strongly influenced by outdoor conditions. The objective of this research is to analyze the future thermal comfort in Vienna's heat-vulnerable areas introducing and comparing three holistic thermal comfort indices. The indices innovative aspect lies in its comprehensive integration of existing standards and combination of indoor and outdoor thermal comfort parameters to create a unified framework for assessing urban thermal well-being and its required building cooling demand.

We transform general future climate projections for Vienna to site-specific urban microclimate data using a digital urban representation of buildings and their environment as input for an Urban Weather Generator. To assess the indoor thermal comfort and cooling energy demand through the indices, detailed building-level energy simulations are conducted in EnergyPlus through Grasshopper-Honeybee, employing the same urban model as context along with relevant building information on construction and use.

The results provide insights into the sensitivity and vulnerability of the case study neighborhood to climate change and Urban Heat Island effects. Additionally, they highlight the varying effectiveness of the proposed indices in capturing the overall heat stress experienced by the local population in their daily lives and the methods ability to illustrate the impact of mitigation strategies.

CATE 2024

The economically disadvantaged communities and building simulation for the heat waves challenge

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Abstract

Our society is entering an era characterized by frequent extreme climates. Temperature extreme weather, such as heat waves, has significant impacts on public health and well-being. A clear adaptive strategy for residents is to use their buildings and the provided thermal insulation, cooling, shading, and green spaces against climate change. Unfortunately, economically disadvantaged communities, which should receive more attention under this climate challenge, may not have suitable residential buildings to protect them from heat waves. It is necessary to investigate how the indoor environments of buildings in these disadvantaged communities will be affected by future heat waves and how this will differ from normal communities. In addition, the Nordic countries, historically not considered vulnerable to heat waves, may also require this understanding to make good preparations.

Therefore, an empirical study was conducted in Umeå, located in northern Sweden, to model the indoor environment of a disadvantaged and normal community under heat waves. For this purpose, the income property rate dataset from the Swedish National Bureau of Statistics was used to identify the disadvantaged and normal communities in the target city. A data-driven approach was designed to automatically collect building attributes for these buildings, including U-values and orientations of building stocks within disadvantaged and normal communities. On this basis, a large-scale simulation of the building stock was conducted to simulate the indoor environment. The indoor overheating was predicted based on the large-scale simulation of possible heat waves. The differences in indoor environment between disadvantaged and normal communities showed the vulnerability of buildings in disadvantaged communities. This empirical research helps to understand the challenges faced by disadvantaged communities in future temperature extreme weather.

Energy-Efficient Cooling and Heating Solutions

Chair: Pablo La Roche

Optimizing Residential Air-to-Water Heat Pump Performance. Insights from Generation, Emission and Load Matching

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Abstract

This paper presents findings from a residential case study that is part of an ongoing field trial aimed at monitoring the in-situ performance of Air-to-Water Heat Pumps. It analyzes how the interaction between the heat emission system, dwelling heat load, and AWHP unit size can influence the overall energy performance of the system. The methodologies used to monitor system performance from November 2023 to March 2024 are detailed in this study. Three stages of system modifications were monitored over the four-month period, with the impact of each stage being assessed before further modifications were made. In the first stage, the heat pump was oversized relative to the dwelling's heating load and the heat emission system capability. In the second scenario, the pre-existing radiators were replaced with radiators that provided greater heat output at equivalent flow temperatures. Finally, in the third stage, the Air-to-Water Heat Pump outdoor unit was replaced by a unit with reduced power output at equivalent air temperatures, aligning the generation capabilities more closely with both the heat emission capabilities and the heat loss of the dwelling. The performance results demonstrate a 74% increase in the ratio of heat delivered per unit of electrical energy consumed by the Air-to-Water Heat Pump between the first and second stages of system modifications and a subsequent 66% increase in the ratio between the second and third stages. The paper provides an operational trend analysis over a 24-hour period for each stage in the modification process. The analysis highlights the altered cycling rates and lengths as a result of system modifications. The paper concludes with a general discussion, including limitations of the study and the significance of its findings.

Evaluating building performance of an existing research laboratory building: energy-efficiency and indoor environmental quality

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Abstract

This paper presents a comprehensive study on energy-efficient (EE) retrofit strategies for improving building performance and indoor environmental quality (IEQ) in a higher-education research laboratory building. The case study is an existing 12,932m^2 (139,200ft^2), five-story research laboratory building on the University of Utah campus - selected due to the availability of construction documentation, actual energy consumption data, and the capability for in-situ equipment installation to monitor actual IEQ data in two representative indoor spaces. The study utilized qualitative and quantitative research methods, including archival research, in-situ measurements, simulations and modeling, and comparative analysis between actual and simulated EE and IEQ. While the full extent of this research includes data collection from August 2023 through August 2024, this paper presents results for the available seven months of the study and predominantly focuses on IEQ data collection and analysis. The case study laboratory building is particularly inefficient regarding its energy use and thermally uncomfortable. Its actual source energy use intensity (sEUI) varied from 146-166kWh/m^2/yr (463-526kBtu/ft^2/yr) during the years of 2020, 2021, and 2022. This very high energy usage is mostly attributed to district hot water. Once normalized, it resulted in an average sEUI of 126kWh/m^2/year (398kBtu/ft^2/yr), 20% higher than the US national median for laboratories. IEQ data revealed different patterns between the two monitored spaces. *Lab 1* recorded elevated indoor temperatures (reaching 29.5°C) between September and November, which then fell below the comfort temperature range (reaching 18.0°C) between November and mid-February. In contrast, *Lab 2* recorded relatively stable indoor temperatures. Both spaces recorded higher relative humidity levels (50%-60%) during August and September, and both recorded CO_2 levels above 500ppm during August. The study pinpoints the need for appropriate design retrofit strategies to enhance the building's energy performance and improve IEQ for occupants' comfort. While a single case, the presented methods are adaptable for laboratory buildings in various settings.

CATE 2024

Technical Evaluation of Exhaust Air Heat Pumps: A Case Study in Irish Social Housing

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Abstract

There is an urgent need to retrofit existing buildings to reduce the heating demand in the built environment. Coupled with this, there is a desire amongst policymakers to electrify heat to benefit from carbon neutral renewable energy. However, the current cost of retrofit and heat pumps more generally can be prohibitive and while individual homeowners may have the means to do so, there is a larger cohort in a social housing setting that will be reliant on solutions offered by the state. Additionally, given the wider heat electrification strategy there is also a need to assess whether small heat pumps such as exhaust air systems are sufficient to maintain comfortable conditions. A technical evaluation was conducted considering the operational cost of systems, the likely comfort of occupants (through indoor environmental monitoring) as well as the performance of the exhaust air heat pump systems in comparison to design values. The overall aim being to determine if the retrofit approach taken was comfortable, cost effective for occupants and energy efficient. Preliminary results indicated that occupants were satisfied with internal conditions in all social homes studied. Despite these internal conditions the energy consumption of these systems was shown to vary considerably depending on the home involved (over 45% difference in annual energy consumption terms). The combined systems were found to have seasonal performance factors that were better than expected (average of 3.2, compared with 2.7) which were like values in the literature. However, it should be noted that while on an annual basis the retrofit of these dwellings was likely to mitigate a substantial amount of energy poverty risk, the cost in some individual months would be seen as being above recommended disposable income thresholds. It is proposed that future work considers these systems in a lot more detail using third-party monitoring systems.

CATE 2024

Quantifying the influence of the adaptive comfort model slope in cooling energy consumption in present and future scenarios

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Abstract

Understanding how people adapt to indoor temperature conditions is crucial to designing places that both improve occupant well-being and achieve energy efficiency goals. The premise behind adaptive setpoint temperatures is that people would adjust to mechanically conditioned spaces by acting as though they were naturally ventilated. Thus far, the potential energy savings of adaptive setpoints have been compared with PMV-based setpoints or building operating strategies based on regional and global comfort models. But there is an absence of a more comprehensive viewpoint that goes beyond certain models and environments. In order to comprehend the adaptive comfort model's influence on energy usage, this research looks at its slope. The Department of Energy (DOE) small office building prototype is fitted with adaptive setpoint temperatures using the Adaptive-Comfort-Control-Implemented Model (ACCIM) tool, while the parametric analysis is carried out using the Building and Energy Systems Optimization and Surrogate-modelling (BESOS) tool. In light of the fact that climate change is anticipated to cause people to adapt to rising temperatures, the Shared Socioeconomic Pathways (SSP) scenario SSP5-8.5 for 2080 is taken into consideration. The results show that increasing the slope of the adaptive comfort model significantly reduces cooling energy consumption, with higher gradients achieving greater savings. Notably, the optimal gradient range of 0.15 to 0.3 achieves substantial energy savings of 18% to 25% for each interval. Moreover, higher gradients, such as 0.8, can achieve energy savings up to 79% in the present scenario and 86% in the future scenario. These findings highlight the potential of adaptive comfort models to enhance energy efficiency in buildings, suggesting it is key to steering the industry towards more energy-efficient standards and achieving climate goals through both mitigation and adaptation measures.

Full-scale facility for night and day-time passive radiative cooling system assessment

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Abstract

As part of the EURAMET research project "Metrological framework for passive radiative cooling technologies" (PaRaMetriC), the aim of the research is to implement a prototype cooling system to assess the potential of passive radiative cooling (PRC) materials and their applicability for achieving thermal comfort conditions in buildings. The experimental setup is based on a full-scale facility located in Arganda del Rey, community of Madrid, Spain. This study describes the characteristics of the radiative cooling system with its different components and the test facility. Previous experiments have demonstrated the applicability of a similar system, based only on nighttime radiative cooling, for less favorable climatic conditions in Curitiba, Brazil. The assessment of the system in full-scale is essential to showcase the contribution of PRC materials can have for ensuring indoor thermal comfort in extreme weather conditions.

CATE 2024

Field Study on HVAC on Optimization of Adaptive Operative Setpoints of a Mixed-Mode Building in Southern Europe

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Abstract

This study investigates the development of adaptive thermal comfort models designed specifically for occupant preferences in a mixed-mode office building located in southern Europe, a region characterized by high temperatures throughout much of the year. The research emphasizes the critical role that understanding occupant thermal preferences plays in optimizing heating, ventilation and air conditioning (HVAC) systems to improve energy efficiency and occupants' thermal comfort. Unlike traditional approaches that rely on fixed temperature set points or population generalized data, this study customizes indoor temperature control based on a previously established adaptive comfort model. By adjusting HVAC operative setpoints to align with the specific thermal preferences of a smaller group of occupants, the study aims to identify how altering the operative temperature range of the system can improve both comfort and energy savings. The results suggest significant potential to reduce HVAC energy consumption while ensuring high occupant satisfaction.

Switchable Cool Roofs for Sustainable Thermal Regulation

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Abstract

Roofs designed to reflect solar radiation, known as “cool roofs,” are a popular low-cost method of reducing urban heat island effect and providing sustainable thermal comfort in warm climate regions. However, cool roofs are non-ideal for regions experiencing mixed climates, for they increase the demand for mechanical heating in cooler seasons, driving up operating cost and energy consumption. This study focused on designing a low cost and low-tech roofing system that automatically switches between heat retention and heat reflection modes based on season and environmental conditions to maximize thermal efficiency and reduce operational carbon. The simulations for the roof in mixed mode climate of Boston show significant energy savings (~4000kWh) by reduction in both heating and cooling energy demands.

Paulownia Wood for Thermal Adaptive Architecture

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Abstract

This research investigates a novel, thermally adaptive architecture for hot climates using Paulownia, a low-density, fast-growing wood species. The strategy involves developing this wood as locally grown CO_2-sequestering material for architectures and explores its use as thermally adaptive and open spatial elements in modular, poetic designs for climates with fluctuating and rising temperatures.
Unlike the common Mediterranean approach, which relies on heavy structures, excavated mineral materials, and enclosed spaces with air conditioning—practices that negatively impact the landscape and climate—this project explores a strategy that enhances the spatiotemporal and thermal adaptability through lightweight elements. It combines their design and use with convective cooling techniques to better align with human comfort, sensory preferences, and adaptive needs. The strategy is investigated, tested, and documented through material geometry and full-scale construction methods in a completed test house in Spain's Valencia region.
Here the modular components are qualitatively evaluated to assess their ability to create microclimates that adjust to occupants' preferences for temperature, light, and space over time and use. In combination with their arrangements, quantitative data from material and environmental sensors is collected to analyze the spaces. This sensor data is then used to calculate thermal sensation, applying heat balance and adaptive comfort theories and models.
The results from the test house, designed as a modular, low-density, and thermally adaptive living unit, along with the calculated thermal sensations based on the presented approach, clearly demonstrate that thermal comfort can be achieved during hot periods. This, however, requires active engagement and Personal adaptation from the occupants.

Social Equity and Inclusion in Extreme Environments

Chair: Veronica Soebarto

Health and well-being during heat waves in social housing: insights into a field study in the Alpine region

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Abstract

In recent years, climate change and global warming have been posing severe concerns on the cooling-dominated seasons. In many areas of the world, some sort of cooling is needed to meeting human fundamental needs for comfort for larger portions of the year and at higher intensity due to the more elevated outdoor temperatures. This is likely to lead to higher energy consumption from buildings (when available and affordable) to lower levels of comfort and potentially health threats (e.g. in more fragile contexts), or to both conditions simultaneously.
The Alpine region is among Europe’s areas most affected by global warming. Locations that used to face mainly comfort and energy issues in winter are now frequently experiencing more problems during the warmer months. Moreover, cities located at relatively low altitude such as Bolzano (Italy) suffer extreme conditions both in winter and summer, and this makes the design of comfortably and energy-efficient buildings even more complex.
In this context, social housing tenants are likely to experience the highest risks, and it is therefore important to focus on them to ensure social equity and inclusion also in extreme conditions. A combination of age, lack of disposable income and non-ownership of the house makes these tenants considerably more vulnerable than average. For this reason, the aim of this research is to investigate (i) how social housing tenants in Bolzano perceive their houses during exceptionally hot periods such as heat waves, (ii) what actions they take to improve their thermal comfort during those periods, and (iii) to what conditions there are exposed. This will set the evidence base to (iv) propose effective energy-efficient comfort solutions.
This paper presents the first insights into a field study conducted in spring and summer 2024.

Field study of indoor environment for autistic people: analysis of the main sources of discomfort in a climate change context

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Abstract

Autistic people represent a relevant and growing share of the world population. In fact, the number of diagnoses has been rising during recent years and is estimated to soon reach 2.8 % of the people living in Denmark. Autism Spectrum Condition (ASC) is often characterized with hyper- or hypo- sensitivity to the 5-senses stimuli. For this reason, autistic people might have different and more restrictive needs in terms of the indoor environment. Moreover, due to their condition and social habits, they might spend more time indoors with respect to the average population. Therefore, in the framework of building resilience, it is fundamental that their indoor requirements are met in the context of climate change. Nevertheless, not many studies about indoor environmental quality and ASC exist. In this work, we analyzed the data from a field study performed in the dwellings of 13 autonomous autistic people in Denmark. During a total period of one year, occupants were regularly asked to indicate their environmental satisfaction and sources of discomfort by means of online questionnaires. In this work, we identified the percentage of dissatisfied occupants and the main sources of environmental dissatisfaction stated by the participants during heating and non-heating season, critically discussing them in relation to the topic of building resilience. Finally, we hypothesized design criteria to be taken into account to overcome the worsening of well-being of the autistic population due to climate change. Our results, if integrated with similar studies, can be exploited to develop guidelines and standards about indoor inclusive and resilient design for autistic occupants.

Mapping Heat, Space, and Segregation: Urban Analytics for Environmental Equity in Seville

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Abstract

This research aims to investigate the influence of Urban Heat Islands (UHIs) and Spatial Configuration (SC) on social segregation and Environmental Justice (EJ). It seeks to understand how UHIs and SC exacerbate inequalities within urban environments and contribute to differential exposure and vulnerability to climate change-related hazards, particularly in Seville.
The research proposes that intensified UHIs, coupled with specific spatial configurations, lead to increased social segregation and environmental injustice within urban areas. Spatial and Remote Sensing data analyses are employed to identify spatial configurations that contribute to social segregation and exacerbate the impacts of urban heat. Using Seville as a case study, the research uses Space Syntax (SS) parameters and GIS data, together with microclimate analytics to delineate Heat Boundaries (HBs), defined by the research as entities aggravating the impacts of urban heat and intensifying social segregation within vulnerable neighbourhoods.
The identification of HBs underscores the importance of considering both physical and social dimensions in mitigating the adverse effects of climate change and promoting equitable access to mitigation and adaptation strategies. Two zones in Seville are analysed, one has disadvantaged neighbourhoods, the other is characterised by cool neighbourhoods and vicinity to the river. High heat exposure corresponds with less integrated and vulnerable areas, suggesting that marginalized communities face greater heat-related health and wellbeing risks.

CATE 2024

Social Vulnerability in Depopulating Rural Communities: A Case Study of Montesinho Natural Park Villages, Portugal

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Abstract

This paper explores the essential parameters that can be used to assess social vulnerability to hazards in rural communities facing depopulation, focusing on four villages within the Montesinho Natural Park in Portugal. This investigation is being conducted within a research project funded by the Portuguese Foundation for Science and Technology (FCT), the INHAVIT project, which aims to evaluate and characterize both the rural built environment of the park and the socio-economic and environmental factors contributing to the vulnerability of villages and vernacular buildings. The main objective of this study is to investigate the social and economic vulnerabilities that may be contributing to the current progressive abandonment of the rural villages within the park.

Data were collected through surveys conducted among the local population to assess social vulnerability. It was used a multidimensional approach encompassing the identification of vulnerable groups, including individuals with special needs and the older people, a socioeconomic dimension with indicators such as income and employment status, and information related to the population's capacity to cope with climate-related hazards.

The findings reveal significant disparities in socioeconomic status and access to resources among the surveyed villages. These differences underscore the region’s varying levels of social vulnerability, contributing to a more comprehensive understanding of the dynamics in rural areas prone to depopulation.

The insights generated from this study can guide targeted interventions aimed at enhancing the resilience of rural communities to climate-related hazards. These interventions may include risk mitigation strategies, socioeconomic development initiatives, and conservation efforts that improve living conditions and reduce vulnerability. Ultimately, such measures seek to promote social equity and foster sustainable development in disadvantaged regions.

Cultural heritage, accessibility and standardization: ISO 5727:2024. Principles and methodology for interventions.

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Abstract

Our society's recent history, from the perspective of accessibility, is marked by a sequence of achievements and overcoming, but at the same time, there is a great lack of knowledge about some broad sectors. specifically, those who are directly involved in facilitating people's relationships through the construction of their environment, such as Architecture and Engineering.

Justification is a necessity; On the one hand, the majority of the population will live in cities that, added to the growing aging of the population, will make the person-environment relationship acquire new dimensions. Thus, to achieve greater well-being of the society, in a social and economic order, the urbanized physical environment and its use will be decisive for its achievement. The balance and adaptation between capabilities, limitations, and demands functions of the built environment have begun to be considered a matter of maximum relevance and key in the future social organization.

In 2005, the member states of the Council of Europe signed in Faro the “Convention of the European Union Council of Europe on the value of Cultural Heritage for society” (Instrument of ratification, 2022), where access to historical heritage is established as a human right. On the other part, just one year later, in 2006, the states parties of the United Nations signed in New York the text of the International Convention on the Rights of Persons with Disabilities (Instrument of ratification, 2008).

Both concepts, accessibility and heritage, and the relationship between them, are the basis of the ISO 5727:2024 standard. Teamwork over three years has resulted in a set of objectives, methodology and examples of good practices at the service of society.

CATE 2024

Improving resilience of existing dwellings of older people in South Australia

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Abstract

Extreme weather events have occurred for many years; however, the intensity and frequency of extreme heat events have increased significantly in recent years while the occurrences of extreme cold events have decreased with lesser significance. Both extreme heat and cold events have significant effects on people's health, particularly for those who are vulnerable, such as older people with low socio-economic status. It is therefore important to ensure that their living environments are able to provide thermally comfortable conditions during such extreme conditions. This study investigated the indoor thermal environment of dwellings of low socio-economic older people in South Australia, where indoor and outdoor environmental parameters were monitored for at least 9 months, during which the occupants regularly responded to indoor environmental surveys. The paper focuses on three of the dwellings investigated, selected to represent common building typologies among the cohort. Indoor temperatures were found to range from below 13 degrees to above 39 degrees Celsius. Existing problems were identified, including leaky construction, lack of insulation, and lack of external shading. Using calibrated simulations, the performance of these dwellings in future climates were predicted. Affordable retrofit strategies with their life-cycle costs were explored, including increasing airtightness, adding ceiling and/or wall insulation and adding external shading devices when possible. Lessons learned from the explorations point to the design strategies that must be implemented in both existing and new housing to ensure resilience in future climates.

Addressing energy poverty from its multifaceted issues

Chair: Teresa Cuerdo

Tenant Perspectives on Building Electrification in Affordable Housing

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Abstract

Low- and Moderate-Income (LMI) tenants are at risk of being left behind in the clean energy transition. While building electrification's environmental and health benefits are evident, it can pose accessibility challenges for LMI residents, who already bear a disproportionate energy burden. Electrification of multifamily LMI housing is particularly challenging due to the complex decision-making dynamics in landlord-tenant relationships, such as split incentives, master-metered gas systems, and capital pass-through costs. Additionally, LMI residents of multifamily housing often suffer from heat stress, lack air conditioning within their homes, or lack the means to afford elevated electric bills from space cooling. These issues are exacerbated by the fact that LMI tenants often hesitate to advocate for improvements due to the fear of retaliation or eviction. The compounded effects of extreme heat, energy burden, and power imbalance threaten the health and safety of LMI residents.

In this study, we investigate air conditioning access for LMI households residing in multifamily buildings and explore the potential role of building electrification in mitigating heat stress. Our mixed-methods approach aims to assess residential building electrification's role in decarbonization and comfort, health, and safety. This study is part of an ongoing effort to understand LMI households' perspectives and concerns regarding building electrification and aims to provide insights that inform equitable policy solutions.

Personal Thermal Comfort in People with Intellectual Disabilities Living in Energy Poverty

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Abstract

Hypothesis: The use of Personal Comfort Systems (PCS) plays a central role in the thermal adaptation strategies of adults with Intellectual Disabilities (ID) living independently in energy poverty, positively impacting their comfort perception.

Objective: To identify the thermal sensation of adults with ID living independently during winter and summer, focusing on the impact of PCS on their comfort perception.

Scope and Limitations: The study involves a small sample of two identical homes where eight individuals with ID (Moderate and Severe) live independently (four individuals per home). These individuals participate in the Supported Living program, which promotes independent living for people with ID through professional support and continuous training in autonomy and daily life skills. Six of the eight participants have paid employment. The case study is in Santiago, Chile, in a continental Mediterranean climate.

Method: An inclusive research approach is employed, valuing the first-person perspectives of individuals with ID. Accordingly, instruments are adapted and pre-study training is provided to facilitate participation. A mixed-methods approach is used, incorporating both qualitative data for individual interviews and quantitative data for indoor temperature measurement and a thermal comfort questionnaire across 10 weeks for winter and 14 weeks for summer.

Novel Conclusions: Among thermal adaptation strategies, PCS are highly utilized by individuals with ID living independently in energy poverty, where there is no access to air conditioning. Other adaptations include clothing adjustments and consumption of hot and cold liquids. Despite PCS use, extremely low indoor temperatures in winter and extremely high indoor temperatures in summer, characteristic of energy poverty, result in low average thermal acceptance in both seasons. Nevertheless, an increase in thermal acceptance is identified with the use of PCS in both winter and summer. The range of acceptable indoor temperatures varies significantly by season, indicating a wide diversity in personal preferences.

Re-defining Energy Poverty

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Abstract

Energy poverty, historically characterized by a household's inability to afford the energy required for adequate heating and powering of their home, has significant repercussions on individuals' health and financial circumstances. Over the last decades, efforts by stakeholders around the world have aimed to understand and alleviate energy poverty through a diverse mix of programs and initiatives, for example, offering energy bill subsidies and/or building retrofit programs. However, current measuring approaches do not capture all households who may be experiencing signs and/or symptoms of energy poverty and, therefore, reduce the effectiveness of the energy poverty programs. More specifically, when identifying households who may be considered energy poor, current methodologies focus on a financial-objective form of this societal ill, neglecting subjective-financial, indoor environmental-objective, and indoor environmental-subjective dimensions of this inequality, Figure 1. This has led to the underestimation of the prevalence, incidence, and depth of energy poverty across society. Further, energy poverty solutions tend to be offered to those who meet some financial threshold, ignoring those who fall below the threshold and/or those whose lived experiences may not be captured under some financial conception. This is particularly relevant when examining comfort at the extremes, specifically short-run, extreme temperatures as well as long-run, average temperatures. The below definition is an attempt to codify an expansion of the conditions that constitute energy poverty.

A household may be objectively or subjectively considered energy poor if there are signs or symptoms that:

a) sufficiently warming or cooling the home results in an excessive burden on the household’s finances, and/or
b) the indoor environment, with a focus on average indoor temperature experienced by the household during the heating and cooling seasons, is likely to negatively impact health outcomes of residents.

Thermal comfort and the feeling of care: Memories of childhood through a qualitative approach

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Abstract

What is the relationship between our feelings and our experiences of thermal comfort? Thermal comfort is defined as 'that condition of mind that expresses satisfaction with the thermal environment' (ASHRAE, 2004). Despite 'that condition of mind', the mainstream of research focuses on the momentary thermal sensation regarding the immediate thermal environment through a quantitative approach. Thus, the subjective nature of thermal comfort and the role of feelings are overlooked. Also, no research has investigated the long term or childhood memories of thermal comfort. This work investigated thermal comfort experiences through recalling childhood memories of parental care and feelings in two deprived and fuel poverty stricken mining community areas in the UK. A novel qualitative approach via oral history interviews of 60 participants between the ages of 45 to 85 was applied in winter between 2022 and 2024. All interviewees mentioned the feeling of being cared for or lack of to keep warm in winter. Lack of parental care was mentioned as carers' awareness of the child's thermal discomfort and their neglect despite their capacity to take actions. On the other hand, parental care was explained as extra effort to ensure the thermal comfort of the child, despite poverty, lack of fuel and working long hours. These carers put the thermal needs of their children before their own and they visibly showed their affection through their efforts in keeping their children warm. Some examples of their planned activities included extra efforts to provide coal for heating; waking up early to warm the room; keeping one room warm for children; knitting warm clothes; and warming the bed before the child goes to bed. Both groups mentioned feeling the cold, however the latter accepted the thermal condition with gratitude and affection, while the former expressed their dissatisfaction and lack of thermal acceptance.

Combating extreme heat inside Korea's poorest housing

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Abstract

This study attempts to understand the extent to which residents are exposed to indoor heat in Korea's poorest housing type, known as "Jjokbang". Jjokbang, a symbol of poverty in South Korea, literally means a 'tiny' or 'divided' room. It offers on overage less than 9m^2 of floor space with no amenities like bathroom and kitchen, and is typically occupied by low-income, single householders. Some dwellings have a window but some don't, and it is rare to have an air-conditioner, making the residents vulnerable to summer heat. Such extreme conditions receive media attention every summer or during heat-waves, but no scientific efforts to objectively quantify the physical conditions the residents are exposed to have been made.
We have recruited a total of 40 Jjokbang households located in Daegu, South Korea to participate in the present longitudinal field study. Instrumental measurements (incl. air temperature, relative humidity and CO_2) and householder surveys were carried out from August 2023. In this paper we report the physical thermal conditions the residents were exposed to during summer months, their perceptions of heat, their adaptive actions to mitigate such conditions. Our preliminary analysis indicated that the physical conditions in the sample dwellings fall far beyond the conventional thermal comfort zone for indoor spaces, with around 80% of the residents expressing thermal discomfort and exhibiting heat stress related symptoms. In this paper we also discuss potential ways to improve the living conditions in this particular housing type.

Consumption indicators, reflections on energy poverty and its effect on environmental conditions, a case study in central-southern Chile.

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Abstract

The one-dimensional and multidimensional Energy Poverty (EP) indicators used worldwide consider objective criteria such as expenditure, income, and consumption of energy resources, as well as subjective criteria such as thermal comfort and housing conditions. However, in some local contexts, these indicators do not address other variables that determine the environmental conditions inside homes that may be affected by EP. This research examines the environmental conditions of homes characterizing their EP using indicators associated with energy consumption, namely M/2 and 2M. As a result, three groups were identified: G1 - EP due to underconsumption; G2 - without EP due to regular consumption; and G3 - EP due to energy overconsumption. According to these indicators, significant differences are observed in the groups' temperature T (°C), relative humidity RH (%), CO_2 concentrations (ppm), Heating Degree-Days (HDD), and percentage of hours in comfort (CH%). However, it was observed that G2, defined as the group without EP, had environmental conditions under the reference thresholds, as did G1, although restricted due to its EP with underconsumption. On the other hand, G3 recorded environmental conditions that remained within the reference thresholds. The results showed, on the one hand, that the T (°C) and RH (%) variables are closely correlated with the household's energy consumption. Similarly, it was observed that with regular consumption, considering the average, households are unable to maintain the environmental conditions associated with the standards. It is felt that these aspects must be considered to complement EP indicators and enact policies for the minimum energy needs associated with the dwellings' environmental health.

Assessment of the impact of climate change on occupants in Arctic housing

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Abstract

The building industry is currently under pressure to adapt to climate change to ensure resilience to extreme weather events and global warming. The effects of climate change have been increasingly perceptible, especially in the Arctic. Moreover, the remoteness and limited resources of most Arctic communities make them ill-equipped to fight and adapt to climate change. It is consequently crucial to develop proper methodologies to design climate-resilient Arctic buildings. The resiliency of buildings greatly depends on occupants, as it is now well known that the thermal behavior of buildings varies drastically according to the occupant behavior (e.g., occupancy, set points, window opening). Therefore, it is important to include the variability of occupant behavior in energy simulations designed for resiliency assessment. This study investigates how occupants of residential buildings in Kuujjuaq (in the Arctic region of Canada) will be affected by climate change in terms of energy consumption and thermal comfort. A numerical model of a residential building was developed and combined with different future weather files for different three time horizons and 1,000 occupant profiles. Through Monte Carlo simulations, it is thus possible to obtain energy consumption and thermal comfort probability distributions depending on how occupants use the building and on how the climate will change in the future.

Energy poverty in Italy. A survey conducted in the Calabria Region on technical, social and behavioral drivers

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Abstract

In Italy, the Energy Poverty (EP) is defined in the National Integrated Energy and Climate Plan and, generally, the phenomenon is associated with the occurrence of three conditions: living in energy inefficient homes, having to face high energy prices, and having a low income. However, scholars proposed additional subjective indicators, introducing a fourth factor: the occupants' behavior.
In 2019, the Italian Observatory on Energy Poverty (OIPE) was founded, and on the back, the Observatory of Energy Poverty of the Calabria Region was born in 2020. The regional Observatory has the aim of supporting the national activities by collecting data useful for activating policies and behavioral measures. Moreover, it collaborates with the National Agency for new technologies, energy and sustainable economic development (ENEA) and the social psychology research group of the University of Milan in a joint research "DE-SIGN: Energy in Calabria" that is a part of the National Campaign "Italy in class A" investigating the role of families in energy consumption. The need to study EP in Calabria is evident from the latest OIPE 2023 report, in which emerges that Calabria is the Italian region most exposed to the phenomenon (16.7% of families are in EP). This investigation is organized in two phases: study on demographic, economic, and social aspects of Calabria by elaborating data from regional and national database; presentation of the structure and preliminary results of a questionnaire targeted to collect technical and behavioral variables. The first analysis identified an elevate percentage of unemployment and a scarce diffusion of energy efficiency improvements. The second analysis highlighted a notable discrepancy between how households perceive the importance of energy-saving practices and their actual behaviors. The size of the household is another critical factor, and there is also a clear relationship between energy poverty risk and the presence of structural issues within homes.

Evaluating User Adaptation and Building Retrofit Strategies to Address Overheating in a Climate Change Scenario: A Focus on Energy Poverty and Vulnerable Users

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Abstract

In the European Union, approximately 50 million households suffer from energy poverty, placing vulnerable groups—such as the elderly, children, pregnant women, the infirm, and people with disabilities—at increased risk of overheating, especially under climate change scenarios. This study investigates the effectiveness in the long-term of passive overheating mitigation strategies for residential buildings, focusing on those occupied by elderly individuals and children up to fifteen years old.

Using a typical 1960s residential building in Milan as a case study, dynamic building energy simulations were employed to evaluate various passive cooling techniques, including natural ventilation and ceiling fans. These strategies were analyzed both pre- and post-retrofit, with the retrofit primarily enhancing building insulation. The results demonstrate that while these passive methods can lower indoor temperatures effectively, they may not suffice to maintain comfort levels in the future, suggesting the need for active cooling systems in retrofitted buildings.

The study further includes a comparative analysis between baseline and retrofit scenarios, assessing the energy consumption, economic impact, and environmental benefits of the proposed strategies. The findings reveal significant improvements in energy efficiency and cost savings, alongside notable environmental advantages with the use of natural ventilation combined with fans.

Additionally, this research emphasizes the importance of incorporating the resilience and adaptability of occupants through phased renovation strategies. By combining lean and deep renovation approaches, this comprehensive framework aims to tackle the challenges posed by climate change, ensuring long-term sustainability and comfort in residential buildings for energy-poor communities.

As a practical outcome, the study proposes a user guide to help residents achieve thermal comfort through effective use of passive and active cooling strategies, ensuring their homes remain livable and energy-efficient in the face of evolving climate conditions.

A study case of energy poor woman-led households before and during the COVID-19 confinement, in Madrid (Spain)

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Abstract

Individuals with lower wages often reside in homes that lack proper thermal insulation, which hamper their ability to maintain a comfortable indoor climate. This vulnerability is intricately linked to the quality and upkeep of housing, adversely affecting indoor comfort, particularly concerning energy consumption, and has repercussions on health and well-being.

Exploring energy poverty from a qualitative standpoint allows for a deeper understanding of these individuals' experiences. A qualitative research study was conducted focusing on women facing housing vulnerability and energy poverty, involving semi-structured interviews with five households led by women and two key informants, both before and after the COVID-19 confinement, in one of Madrid's most at-risk neighborhoods.

The investigation revealed the complexity surrounding this issue and identified three main categories: 1) household structure and financial resources, 2) perceptions and recommendations for home improvements, and 3) the overall health and well-being of households.

Additionally, the findings indicate that the dependence on ineffective heating methods, such as electric radiators or butane heaters during winter (which may seem cheaper initially but are unsustainable long-term), reflects energy instability. This, combined with adverse housing conditions and behaviors of residents, significantly affects health and can exacerbate chronic illnesses.

Research focusing on vulnerable populations needs actions that go beyond mere awareness, supported by key informant insights. Social workers and educators play a crucial role in enhancing the living conditions of the most deprived individuals; however, they require the backing of social policies and well-crafted intervention plans and strategies to make their efforts successful.

Education Strategies for Resilience in Extreme Environments

Chair: Jessica Fernández-Agüera

Understanding Adaptive Opportunities and Indoor Environmental Quality Experiences for Aging in Place: A Pilot Study

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Abstract

Many older adults prefer to remain in their homes, or "age in place", instead of moving to retirement homes or assisted living facilities. In the context of the challenges posed by globally aging populations, increasing extreme events from climate change, and the vulnerability of older adults to these extreme events, it is crucial that indoor environmental quality (IEQ) in homes sufficiently supports the health of those aging in place. People can improve IEQ–and thus their comfort and health–by using adaptive opportunities. Adaptive opportunities are building systems or personal actions that improve actual or perceived IEQ conditions. Increased usability of passive building features may foster sustainability because it enables occupants to achieve comfort with less energy-intensive behaviours. Adaptive opportunities must be accessible for occupants to use them. Thus, the availability of adaptive opportunities must be considered alongside the occupant's abilities, awareness, preferences, and finances. This paper describes a pilot test of a field study investigating the availability, use, and rationale for use (i.e., "when" and "why") of adaptive opportunities among older adults (i.e., 60+ years old) aging in place using home walkthroughs and interviews with five participants in Ottawa, Canada. Participants did not have a clear trend for prioritizing building versus personal adaptive opportunities. Thematic analysis of interviews revealed reasons participants use adaptive opportunities include availability, effectiveness, and co-benefits of adaptive opportunities, personal preference, sensitivity to IEQ conditions, and social factors. Reasons participants do not use adaptive opportunities include poor usability, ineffectiveness, or non-necessity of adaptive opportunities or participants' unawareness, tolerance to IEQ conditions, social constraints, or personal preferences. The results will inform an ongoing field study and help develop a novel tool for assessing adaptive opportunities in older adults' homes to inform guidance on achieving healthy IEQ.

CATE 2024

Representing Climate Extremes: An Event-Driven Approach to Urban Building Performance Assessments

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Abstract

As climate extremes become more frequent and severe, understanding their impact on building design and performance is critical for making informed, resilient design decisions. Traditional Typical Meteorological Year (TMY) files, used in building simulations, fail to capture the severity and variability of extreme heat waves and cold spells. Building on earlier work that introduced Representative Meteorological Year (RMY) files, derived from 15 years of Actual Meteorological Year (AMY) data, this study uses RMY files to more accurately capture the frequency, intensity, and duration of extreme events. These files provide critical insights into indoor and outdoor thermal stress, enabling more robust analyses of performance under extremes. Our methodology integrates multiple anomaly detection techniques—threshold-based detection, Extreme Value Theory (EVT), and Graph Neural Networks (GNNs)—to robustly identify and quantify heat waves and cold spells. Using RMY data, we assess key performance metrics, such as overheating hours and Universal Thermal Climate Index (UTCI) extremes, to evaluate the impact on occupant comfort and building resilience. This framework was applied to six diverse climates, where it successfully captured and validated extreme events. In a moderate climate like Madrid, RMY simulations revealed an increase in annual overheating hours of up to 21% for thermal mass buildings and 14% for lightweight buildings, compared to TMY baselines. Thermal mass buildings proved resilient to short, intense events but vulnerable to prolonged heat waves, while lightweight buildings were more sensitive to peak heat intensity but recovered quickly after events. These findings highlight the critical relationship between heat wave frequency and indoor overheating, as well as cold spell frequency and outdoor thermal stress, underscoring the need to account for both extremes in design. By focusing on extreme weather events, this research offers a clearer understanding of when and where these events affect building performance, providing a crucial pathway for informing design strategies and optimizing cooling needs.

Exploring Air Quality: How Materials Make a Difference.

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Abstract

This study is part of the European EDIAQI (Evidence Driven Indoor Air Quality Improvement) project, in which the value to develop training material for both the early childhood population and the rest of the population on indoor air quality.

In 2021, after the publication of the report analyzing the educational plans of 50 countries around the world, UNESCO warned that it was urgent to make environmental education a central component of the school curriculum in all countries before 2025, since in more than half of them there was no reference to climate change or environmental pollution. This study, associated with the European EDIAQI Project, aims to make a contribution to the awareness and sensitization of the entire population on this urgent environmental problem.

Several studies have highlighted the importance of children's environmental education on environmental attitudes and lifestyles in the adult stages. All of them have something in common; they suggest that the implementation of environmental awareness activities in early stages, together with the example set by the students' environment, are key positive “input variables”. And they add that together they predispose the person, when they reach adulthood, to take an interest in the environment themselves and to work for its protection.

The primary objective of this study is to develop learning and working material to carry out understanding and awareness activities with students from an early age. All this is done in order to educate and inform students and their environment about IAQ, thus promoting their concern and awareness on the subject.

Different training materials (audiovisual and physical/digital) have been developed for different school stages. Materials have been developed for the first (5 to 12 years old) and second stage (13 to 18 years old). Training materials are made to provide information and education through environmental experiences. In addition, information materials have been developed to raise awareness among the rest of the population.

The study seeks to apply these educational tools to increase knowledge, concern, and involvement in IAQ-related issues. By fostering environmental education from an early age, the project aims to build a more informed and proactive population, including students, educators, and society as a whole.

Integrating Regenerative Design in Architectural Education: An Approach to Resilience

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Abstract

Over the past half-century, environmental concerns have been the main drivers for demands from building professionals for the design of high-performance and sustainable built environments. Regenerative design goes beyond it and offers not only to preserve the environment but also to revitalize and regenerate to have net positive environmental advantages for the living world. Such a paradigm shift entails integrating regenerative design into architectural education.
This paper illustrates the use of a research seminar course as a student-centered learning environment for promoting a collaborative approach to educate architecture students about the principles of regenerative design. Student groups research on selected topics from real-world scenarios and examine the phenomena through a set of seven categories and 30 Key Performance Indicators (KPIs) in the domain of regenerative design. Firstly, the students familiarize themselves with the existing literature related to the topic; outline a methodology; carry out primary fieldwork to collate data, and critically analyze and reflect upon it utilizing discussion within the research group. Thereafter, the students synthesize research findings/conclusions in their term papers and also make their presentations to visiting critics and live audiences. The focus of the research is on resilient design strategies for the built environment and how they relate to regenerative design, whether in harmony or opposition.

This paper presents key outcomes of one semester of research done by the fourth-year undergraduate architecture students, respective guides, and coordinators engaging with this course at the School of Planning and Architecture, New Delhi during fall 2022. The findings of this paper are significant in providing a framework for integration of Regenerative design in architectural education.

CATE 2024

Evaluation of Building's Sustainability Actions in Higher Education: A Comparative Study of University Campuses

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Abstract

This paper presents a comparative study of sustainability ratings and action plans for two university campuses: Institution 1 in the USA and Institution 2 in Turkiye. The study evaluates the effectiveness of the Sustainability Tracking, Assessment & Rating System (STARS) and UI GreenMetric ratings in addressing the challenges posed by extreme climate conditions. Specifically, it investigates how these rating systems incorporate action plans to use of technology, to mitigate the impacts of extreme weather events and to further engage with the community. We performed detailed interviewed 5 staff from both facility management department of sustainability office at both campuses to gain deeper insights into their sustainability practices and infrastructure responses. A key focus is placed on energy consumption patterns, architectural and urban planning, and the specific challenges faced in implementing sustainability actions. Our findings suggest that the STARS rating system offers a more comprehensive and detailed framework for assessing sustainability, particularly in terms of energy efficiency, climate resilience, and long-term planning. This aligns well with the insights provided by interviewees at institution 1, where the implementation of sustainability measures, including LEED-certified buildings and renewable energy projects, has been highly structured and effective. Conversely, UI GreenMetric, while useful for benchmarking environmental performance, was found to offer less depth in reporting and implementation strategies. The study highlights the need for further investigation into STARS and UI GreenMetric and deeper engagement with the sustainability offices, facility managers and faculty for higher education institutions from different universities to fully understand its limitations and opportunities for improvement. Overall, we concluded that while sustainability rating systems provide valuable frameworks, their effectiveness in driving real-world action depends on localized challenges, commitment, and the depth of engagement with the systems.

Sustainable Infrastructure for Extreme Climates

Chair: Carlos Rivera

CATE
2024

Application of Windcatchers and Evaporative Mist Cooling to Mitigate Pedestrian Heat Stress in Urban Environments

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Abstract

In highly populated urban areas, where buildings are clustered closely together, street-level airflow is often relatively limited compared to the open air above rooftops. In addition to restricted airflow, the urban heat island effect contributes to higher temperatures at the pedestrian level. These conditions impede heat dissipation from the human body, thereby compromising thermal comfort in hot climates. To mitigate the adverse effects of urban heat islands in hot climates, this study evaluates the individual and combined performance of windcatchers and mist cooling systems as sustainable cooling strategies for enhancing outdoor thermal comfort in urban microclimates. ENVI-met urban simulation engine was adopted to model the urban microclimate and analyze the impact of these interventions on thermal conditions and human comfort.

The findings revealed that windcatchers have the potential to significantly enhance pedestrian-level air velocities in typical urban canyons, even in conditions with a moderate free stream air velocity of 3 m/s at a 10-meter elevation, increasing speeds from 0.17 m/s to 0.41 m/s. On the other hand, mist cooling systems effectively reduced air temperatures by up to 2.7 °C across substantial areas of the canyon in the hot and arid climatic conditions of Riyadh during a summer day. The combined use of windcatchers and mist cooling achieved a larger drop in air temperature compared to mist cooling alone (up to 3.4 °C), while also slightly enhancing air circulation in the canyon compared to windcatchers, and providing a more focused cooling impact, offering a promising solution for improving pedestrian comfort and mitigating urban heat islands.

CATE 2024

Thermal Indices for Urban Climate Walk Measurements and Simulations

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Abstract

Thermal variability is essential for assessing outdoor thermal comfort and walkability in urban areas, as it provides thermal-adaptive and alliesthesial opportunities along a walk. This is evidenced by temperature fluctuations that promote passive, intermittent cooling and warming through radiation, convection, and evaporation among buildings, trees, and water bodies. These cooling and warming spots facilitate thermal recovery for pedestrians, as reflected in their metabolic rate, skin and core temperatures, and sweat productions. This paper investigates dynamic thermal comfort along a 3.6 km walk in Rome, Italy, using mobile measurements and simulations (ENVI-met, BIO-met, and Rayman) to explore dynamic thermal indices for forecasting thermophysiological changes due to sun and wind. Two novel thermal indices, $dPET$ and $mPET$, were compared with the static PET maps under non-extreme (September 2021) and extreme (July 2022) weather. The results indicate that both indices capture the temporal progression of environmental and personal parameters. However, they exhibit distinct spatial-temporal patterns owing to their sensitivity to fluctuating thermal conditions. The discussions highlight the need for further lab and field thermophysiological studies to improve dynamic thermal indices for urban climate walk simulations.

CATE 2024

Method development to assess levels of design indoor environmental quality in a geometric and questionnaire bases way to evaluate residential buildings

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Abstract

Background: Climate change is influencing our living environments and challenging us to reduce resource demands. Regarding residential buildings a high amount of resources are used to provide thermal comfort and safety. Transitioning to efficient and comfortable buildings needs identifying design parameters meeting occupant needs, functionality and climate responsiveness. Therefore, this study aims to develop a method to quantify building design Indoor Environmental Quality (design IEQ). Design IEQ is used as an extension of the physical IEQ domains (thermal, visual, acoustic and olfactory). Design IEQ includes a high variety of design aspects. Exemplary results for openness to the outdoors are included, to evaluate their effect on occupant evaluation and thermal comfort. As design IEQ is also referred to as intangible IEQ in literature, a simple and generalizable approach is presented to include it in building evaluation.
Methods: The study with N=42 participants (N_{female}=20, N_{male}=20, $N_{diverse}$=2) took place in 2023 in Wuppertal at the Living Lab NRW including 7 houses. Objectively, the design IEQs are calculated geometrically, and the physical IEQs are measured (e.g. temperature). Subjectively, the effect of physical and design IEQ variables on perception, evaluation and preference are evaluated through a repeated questionnaire. The common questionnaires for assessing physical IEQ have been extended to include design IEQ.
Results: The combination of measured and surveyed data is used to connect human perception with building design. For instance, the openness to the outdoors is associated with thermal comfort, which helps to identify a design also suitable for hot summers.
Conclusion: The method presented suggests an simplified approach to measure and compare design IEQs and furthermore connect them to physical IEQs. The exemplary data demonstrates the application of the suggested method, giving an example for evaluating any design-related IEQ parameter of interest.

It's hot below: thermal discomfort due to subsurface urban heat islands

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Abstract

The phenomenon of Subsurface Urban Heat Islands (SUHIs) is an emerging concern for urban settlements around the world, which often exhibit rising and extreme temperatures in the underground. On the one hand, these temperature variations are caused by anthropogenic activity, inefficient civil infrastructure and systems, and other localized drivers that reject heat into the ground. On the other hand, this problem is exacerbated by the diffused influence of global warming and heat waves. As a result of this phenomenon, subterranean built environments like the London Underground show significant temperature anomalies, often corresponding to air temperatures that are even higher than those found at the surface of London throughout the year. This study investigates the influence of SUHIs on the experience of people traveling underground through mass transit systems. To explore this problem, we used crowdsourced information about user experiences in the London Underground collected with web-scraping techniques. Using natural language processing methods, we analyzed these reviews to identify patterns of discomfort related to excessive temperature. Our dataset comprised 35,906 posts scraped from two online platforms, among which 7403 posts were related to thermal complaints. The analysis highlights significant temporal variations in user experience, with widespread thermal discomfort among users increasing over the years, a considerable gap related to the COVID-19 pandemic, and peaks of discomfort occurring in July. Gender-based analysis indicates that males reported higher levels of discomfort compared to females. These findings shed light on uncharted comfort issues in subsurface urban environments and underscore the urgent need to develop mitigation strategies for SUHIs. Improved ventilation, innovative cooling technologies, targeted operational interventions, and comprehensive urban planning and building renovations are critical to enhancing user comfort and reducing the adverse impacts of SUHIs on people in London and beyond.

Low-carbon building components for a heat-resilient architecture: Design framework and impact assessment

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Abstract

Integrating multiple functions into a single building component is typically regarded as a strategy that leads to better overall performance and reduced costs compared to implementing each function separately. In the context of the current climate crisis, this becomes an opportunity to improve the heat resilience of buildings in a low-cost and low-carbon way, embedding passive and low-energy cooling strategies into building components required in most buildings. Yet, there is a shortcoming of generalizable frameworks that guide the design of building components for multifunctionality. This paper presents a novel framework that leverages recent advantages in computational design tools for the early-stage design and evaluation of multifunctional building components, i.e., those components that collapse multiple functions into a single element, often using a simplified material palette. The proposed framework drives the analysis of three different components based on previous work from the authors: (1) concrete slabs as chilled radiant ceilings, (2) extruded ceramic blocks as thermally massive walls, and (3) footings and roofs as heat dissipation systems. The assessed case studies evidence how the presented framework provides a consistent structure that conceptually guides the design of multifunctional components and, more importantly, results in low-carbon components with improved thermal performance. Beyond these three components, this work hopes to promote and support future design explorations that investigate other multifunctionality opportunities.

Harnessing Traditional Living Experience to Foster Resilience in Modern Living

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Abstract

Vernacular dwellings like yurts (nomadic tents) can be drastically different from modern housing, yet they offer valuable lessons for enhancing the resilience of contemporary inhabitants. This study compared indoor temperatures during winter in modern timber apartments with those in yurts used for different lifestyles. Indoor air temperatures were measured in 4 nomadic yurts in Tuva, 2 urban yurts (*gers*) in Mongolia, and a camping yurt in Switzerland during winter 2019-2020. Two modern timber dwellings in Switzerland had measurements taken in Jan-Feb 2021. For the urban yurt scenario, three different heating methods (a cast-iron stove, an electric heater, and a combination of both) and two envelope options (traditional cover U=0.9 W/m^2K and improved insulation U=0.4 W/m^2K) were evaluated. The outdoor winter air temperature was -22.6±3.8°C in Tuva and -16.4±6.7°C in Mongolia, compared to +2.3±3.7°C in Switzerland. Indoor temperature variations were significant in the yurts using traditional heating methods like a cast iron stove (14.1±11.2°C in yurts and 23.4±8.2°C in gers). However, when an electric heater and additional envelope insulation were introduced in gers, the temperature variation decreased twofold. The indoor temperature variation was minimal (21±1.8°C) in the modern, well-insulated (U=0.14 W/m^2K) apartments with radiant floor heating. As lifestyles shift from nomadic to modern sedentary, people spend more time indoors, disconnecting from the natural environment. Switching to modern heating methods helps maintain remarkably consistent indoor temperatures, regardless of occupant presence. Modern apartments, equipped with climate control and insulation, maintain a narrow range of indoor temperatures, while nomadic yurts allow for much less temperature regulation despite extreme outdoor conditions. Relying heavily on strict indoor climate control may lead occupants to expect a narrow comfort range, which could make them less resilient to the extreme temperature shifts brought by climate change. To address this, modern building designs should allow for a wider range of indoor temperatures, helping occupants build tolerance and adapt to changing outdoor conditions.

CATE
2024

From Sustainability to Regeneration: Assessing the role of an urban green space for human well-being

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Abstract

Sustainable design has long been a key priority in architecture and urbanism. However, there is increasing awareness that mere sustainability is not enough to tackle the urgent environmental and social issues of our time. To achieve a real impact, we must embrace regenerative practices in architecture. Under this premise, the present work delves deeper into the concept of regenerative design and its application to a real case study with the aim of promoting restorative architecture that nurtures both people and cities. The case study, located in the city of Seville (Spain), involves the renaturation of a currently neglected area where, until the mid-20th century, an urban stream used to run through. The project, which consists of the creation of a leisure and climate refuge area in the form of a new urban park, adopts the holistic vision of regenerative design. This assessment encompasses the interconnection of natural systems, the inspiration from nature's strategies and social patterns, and the creation of spaces that promote well-being, equity, and community engagement. For the optimization of the nature-based solutions and the passive conditioning of the space, a field monitoring campaign was performed, and both the current state of the intervention area and the proposed new infrastructures were modelled using ENVI-met software. These models considered not only the current microclimatic and thermal comfort potential improvements but also those of the future according to projections for the second half of the present century. The results of the analysis demonstrated the feasibility of the proposed intervention and the improvement of climate resilience in the medium and long term. Significantly, one of the most impactful strategies proved to be the use of water as a cooling resource, up to 3oC less at the hottest time of day. Moreover, this decrease would virtually compensate for the Urban Heat Island effect in the analyzed area and, in addition, it confirms previous urban planning failures of relocating the original natural water flow.

Conceptual Framework for Resilience Assessment of Smart Energy Systems' flexibility provision

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Abstract

Smart energy systems are crucial for ensuring sustainable, efficient, and reliable energy distribution in the context of intensifying climate change and rising global energy demands. Over the past decade, the provision of demand-side flexibility within these systems has emerged as a critical factor in enabling the grid to manage supply and demand fluctuations seamlessly. This flexibility supports the integration of renewable energy, enhances operational efficiency, reduces costs, lowers carbon emissions, maintains occupants' thermal comfort and improves energy security. Hence, ensuring the resilience of such a complex system becomes essential. These disruptions can be due to short-term (e.g., heat waves) or long-term (e.g., climate change) environmental phenomena, technical failures and human-induced events. This paper aims to develop a conceptual framework for resilience assessment to empower stakeholders to design, implement, and maintain robust energy systems. The study identifies the key components of building energy systems which are HVAC systems, PV, energy storage (EV, battery), electrical appliances, smart meters and grid interaction. The authors also examine the literature to gather state-of-the-art qualitative metrics commonly used for analyzing system resilience. The identification of the above-mentioned metrics is done both at the individual component- and whole system-level. The framework's purpose is to represent and evaluate a building's resilience level at any instant in time. A simulation-based case study with different cooling system and weather conditions are analyzed to showcase how the framework can be used. Key metrics reveal significant declines in resilience during heat waves, including drops in temperature stability, rapid depletion of energy reserves, and increased carbon emissions. To address these gaps, strategies such as adding redundant cooling systems, optimizing energy reserves, improving recovery processes, and fostering adaptive learning are recommended. Building owners and utility providers can use this information to enhance the resilience of their energy systems, ensuring stability and efficiency despite disruptions.

Thermal comfort evaluation

Coping with the heat in slum buildings in Rio de Janeiro: Fieldwork and analytical studies to support the self-built practice

[1]Patricia Paixão, P.P., [2, 3]Joana C. S. Gonçalves, J.G. & [1]Eduardo P. Pizarro, E.P., [1]Andre Sato, A.S.

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Abstract

In Brazil, the most populated country in Latin America, approximately 11 thousand *favelas* (local terminology for slums) are the home to around 16 million people (census 2022). The city of Rio de Janeiro (latitude 23°S) has the largest territory covered by slums in the country - approximately 19%. Given the warm and humid conditions of the local climate, natural ventilation and shading are key strategies for thermal comfort in buildings throughout the year. In this context, this paper presents a closer look to the reality of the environmental conditions in a *favela* in Rio de Janeiro - Community *Morro Azul*, drawing on the outcomes of an empirical evaluation, followed by analytical studies for alternative scenarios and improved internal conditions. Exposed brick walls, small windows and light-weight metal roofs were seen as usual features related to overheating. In the worst-case scenario, measurements *in loco* showed peak indoor temperatures reaching 38°C whilst outdoors temperatures were around 28°C. To cope with hot conditions, almost 90% of the occupants use mechanical funs and 52% declared the use of air- conditioning. The outcomes from fieldwork informed a series of alternative scenarios with the ultimate objective to improve thermal resilience. Among the main results, it was seen that applying plaster to the outside of external walls has a relevant effect on lowering peak internal temperatures (by more than 3°C). In addition, shading of windows and slabs as well as opening windows 100% for natural ventilation can drive internal peak temperatures up to 3°C below the external, avoiding thermal stress and improving quality of life.

CATE
2024

Seasonal and regional differences of preferred temperature indoors and in semi-open spaces in Nepalese houses

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Abstract

This study investigates regional and seasonal variations in preferred temperatures for indoor and semi-open spaces in Nepal, including Banke, Bhaktapur, Dhading, Kaski, Solukhumbu, and Mustang districts. The regions span diverse climatic zones, from subtropical to cold, which significantly affect thermal preferences. Data were collected through thermal measurements and thermal comfort surveys in both summer and winter. Results revealed that lower-altitude regions, such as Banke, prefer warmer indoor temperatures, particularly during winter, compared to higher-altitude regions like Mustang. The preferred indoor temperature was higher in summer (21.1–31.8°C) than in winter (10.9–24.2°C) across all districts. Differences were also observed between seasons, with individuals generally favoring cooler indoor temperatures in summer and warmer temperatures in winter. The findings highlight the need for tailored housing improvements based on regional climatic conditions to improve thermal comfort in urban and rural areas of Nepal. Understanding these preferences can help in designing more sustainable and climate-responsive buildings.

Thermal Comfort, Ventilation, and Mosquito-Borne Disease Risk: A Preliminary Field Study of New Hospitals in Zanzibar, Tanzania

[1]Otis Sloan Wood, [1]Jakob Brandtberg Knudsen, [2]Karin Linda Schiøler, [2]Michael Alifrangis, [3]Eliza Lupenza, [3]Gloria Ceasar, [4]Mwinyi Msellem [5]Fatma Saleh

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Abstract

This field study investigated the thermal comfort and indoor air quality in four newly constructed district hospitals on Unguja island, Zanzibar, and their potential impact on the transmission of mosquito-borne diseases (MBDs) like dengue and malaria. The research was conducted over a 48-day period, measuring air temperature, relative humidity, CO_2 levels, and door opening frequency in various hospital spaces, including wards, clinics, offices, and waiting areas. Thermal comfort was assessed using the Predicted Percentage Dissatisfied (PPD) index. The study found that most spaces failed to meet ASHRAE 55 thermal comfort recommendations. CO_2, a known mosquito attractant, frequently exceeded 530 ppm, the estimated threshold for mosquito detection, particularly during night hours.The research revealed a complex interplay between building design, thermal comfort, and potential MBD transmission risk. Ward spaces consistently showed higher temperatures, greater PPD values, and higher CO_2 levels compared to other areas. These conditions, coupled with increased door opening during night hours, could potentially increase the risk of MBD transmission. Air-conditioned spaces, while sometimes achieving better thermal comfort, often had higher CO_2 levels due to poor ventilation.The study suggests that passive design strategies, such as improved shading and natural ventilation, could be more effective and sustainable solutions for enhancing thermal comfort and reducing MBD transmission risk. This research highlights the importance of considering thermal comfort and ventilation in healthcare facility design, particularly in regions with high MBD prevalence. The findings have significant implications for future healthcare infrastructure projects in Sub-Saharan Africa, which will require the construction and renovation of space for 2.5 million additional beds by 2030.

CATE 2024

Comparison of thermal environment of traditional and modern houses during summer in cold climate of Nepal

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Abstract

Traditional house is one of the architectures which exists since starting of human being. These houses are different depending on area, climate, and local culture. Which are designed to be sustainable and energy-efficient, especially in terms of thermal performance. The thermal performance of traditional houses is optimized to provide comfort to occupants in different seasons and climates. On the other hand, modern houses often utilize reinforced concrete for durability, along with insulation materials that enhance energy efficiency. Local stone and wood may also be incorporated for aesthetic purposes. The designs are often more open and spacious, with large windows to allow for natural light and passive solar heating. Flat roofs remain common, but some houses may also have slightly pitched roofs. Thus, in this study, we clarify the thermal environment of traditional houses and the modern houses of Nepal. In this study, traditional houses and modern houses were investigated. In the compression of globe temperature and outdoor temperature the coefficient of determination for traditional house is higher than that of modern concrete house. The variation of indoor air temperature of traditional houses was higher than that of modern concrete houses. From the relationship of globe temperature and indoor temperature, the regression coefficient of traditional house was lower than that of modern concrete house. However, the relationship is highly correlated to each other as coefficient of determination was high which is 0.98 for both traditional and modern houses. Moreover, the findings may be fruitful for policymakers, architects, and local communities about the potential implications of architectural choices on indoor comfort and environmental resilience.

Literature review on comfort temperature, adaptive model and clothing insulation in dwellings

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[2] Tokyo City University, Japan

Abstract

There are many studies in the context of thermal comfort in dwellings and parameters such as outdoor air temperature, indoor air temperature, clothing insulation and other environmental factors have been considered. This review paper mainly evaluates the relationship of comfort temperature with outdoor air temperature, indoor air temperature and clothing insulation. Research articles based on thermal comfort in dwellings are used from the Scopus database for this study. Comfort temperature is influenced by climatic, geographical, and seasonal factors, with significant variations observed across different regions. Comfort temperatures vary widely, ranging from as low as 10.7°C to as high as 29.1°C, reflecting the diverse thermal comfort preferences. This regional variation underscores the adaptation of comfort temperatures to local environmental conditions. The correlation between indoor and comfort temperatures indicates that as indoor temperatures increase, comfort temperatures tend to rise as well. Comfort temperatures generally rise with increasing outdoor temperatures. Additionally, comfort temperature is inversely related to clothing insulation levels; higher clothing insulation corresponds to lower comfort temperatures, and vice versa. These findings highlight the adaptive nature of comfort temperature preferences and the critical role of appropriate clothing insulation in maintaining thermal comfort across diverse environmental conditions.

CATE 2024

Study on thermal comfort zone for various climates of Nepalese dwellings

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Abstract

Due to the altitudinal variation of Nepal, it has various type of climates such as subtropical, temperate and cold. In order to adjust thermal environment, the traditional dwellings are well adapted in each climate and culture. Since residents spend most of their time indoor, the thermal environment of dwelling plays an important role in their physical and mental health. There is some research on the thermal environment and comfort temperature of Nepalese dwellings. However, there is no research thermal comfort zone of Nepalese dwellings which is crucial for understating thermal comfort of residents. The objective of this research are to analyze the thermal comfort of residents and to investigate the thermal comfort zone for various climates of Nepalese dwellings. Two survey of the thermal environment and thermal comfort were conducted in the indoor and semi-open spaces of traditional dwellings during both in summer and winter in six districts of Nepal: Banke, Bhaktapur, Dhading, Kaski, Solukhumbu and Mustang. 9- point thermal sensation scale was used for data collection. The surveys were carried out for 44 days, gathering a total 8700 thermal sensation vote from 139 residents. The thermal comfort band is 10 to 30 ^{o}C indicating large seasonal difference in adaptive thermal comfort. The findings of this research indicate that people are adapted well to extreme cold and hot climates, and the investigated dwellings successfully maintained a good indoor thermal environment.

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Adapting to Heat – Enhancing Resilience and Sustainability in Indoor Environments

21st of NOVEMBER 2024

Hannah Pallubinsky / Marcel Schweiker / Runa Hellwig / Alessandra Luna Navarro

It is clear that climate change will impact everyone in the future, and we must prepare for its consequences on our daily lives. This workshop will feature pitch presentations on climate change impacts on thermal environments at our homes and workplaces, as well as human physiology and health. An interactive session will follow, encouraging debates on e.g. allowing more seasonal and daily thermal variations indoors for resilience and reduced CO_2 footprints. Participants' insights will be collected (anonymously) to inform future discussions and publications on sustainable climate adaptation. Join us to help shape resilient, healthy indoor spaces in a warming world.

Topics:

- Heat tolerance, physiological adaptation and health risks in humans
- Behavioural adaptation: Adaptive opportunities and design aspects
- Human-Building-Resilience and psychological adaptation
- Challenges in building design / assessments of heat resilience

EDIAQI

Evidence driven indoor air quality improvement

How can we convert scientific research into effective policies on indoor air quality?

20th of NOVEMBER 2024

Vanda Jakir / Mario Lovrić / Eva Pualusberger/ Alex Borg / Samuel Domínguez

Indoor air quality is an emerging threat that is claiming millions of lives annually. Research shows that people in developed countries spend up to 90% of their time indoors. Despite this, there is still a relatively limited understanding of the subject. In this session we will discuss the innovative research being carried out in Europe, through projects such as EDIAQI, and how this new data and knowledge can be channelled into ongoing and future policies.

Topics:

- Indoor air quality.
- Low-cost monitoring devices.
- Characterisation of pollutants.
- Science-based evidence for policies.

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Coordinated Use of Fans and Air Conditioning

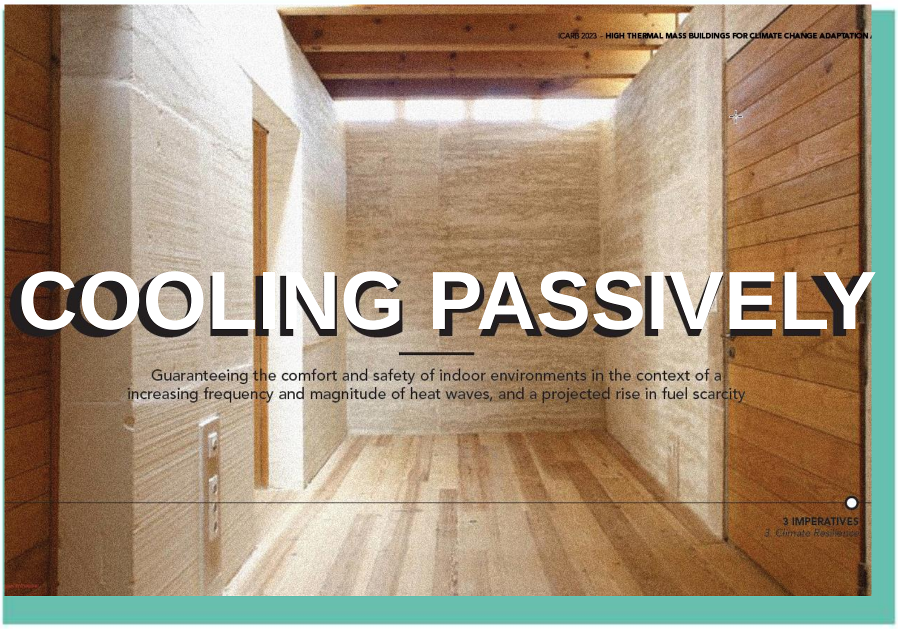
20th NOVEMBER 2024

Samuel Domínguez, David Gómez, Charlie Huizenga

This workshop explores innovative approaches to the use of electric fans in indoor environments, highlighting their potential to address challenges related to thermal comfort, energy efficiency, and resilience. The discussion focuses on the safe application of fans during heatwaves, their unexpected role in improving energy savings during winter, and the barriers or opportunities presented by current building standards for fan integration in indoor design. Experts will share insights on coping with control and data monitoring systems and introduce tools, R&D facilities, and an open invitation to contribute to a collaborative data repository.

Topics:

- Safe application of electric fans during heatwaves
- Energy savings potential of fan use in winter
- Building standards as barriers or enablers for fan integration
- Tools and R&D for control and data monitoring systems
- Open database for hybrid cooling strategies



HERIOT WATT UNIVERSITY

Bouygues Immobilier

GUtech RWTH AACHEN
German University of Technology in Oman

EXTREME COMFORT & HIGH MASS BUILDINGS

20th NOVEMBER 2024

Susan Roaf, Alexander kader

We propose that buildings themselves must become our first line of defense against rising inequalities, fuel costs and scarcity, and record-breaking temperatures in a heating world. To achieve this, high levels of thermal mass enable buildings to store energy and shift and shave temperatures to improve comfort with no- and low-cost passive heating and cooling systems. High-mass building materials can leverage locally geo-sourced materials such as natural stone or rammed earth, as well as exciting new low-carbon, high-mass products including concrete and bricks with a view to reducing total and embodied carbon emissions and whole-life maintenance while increasing durability. Join us to share your research and thoughts with us in this ideas forum.

Topics:

- Climate-Adaptive Architecture and Design
- Energy-Efficient Cooling and Heating Solutions
- Health and Well-being in Extreme Environments

HCB Network
Human-Centric Buildings for a Changing Climate

Human-Centric Buildings for a Changing Climate

20th NOVEMBER 2024

Julia Day, Zoltan Nagy, Liam O'Brien, & Marianne Touchie

Building upon the success of Annex 66 and 79, IEA EBC Annex 95/Users TCP project will undertake a comprehensive exploration to understand the evolving role of humans in the energy transition to address climate change. The influence of people on building energy consumption is profound - from everyday behaviors and purchasing decisions to how they act within buildings, interact with each other, cope, and survive during extreme events. This workshop will introduce the five-year project and then open the discussion to help set a research agenda of most critical areas and promising opportunities.

Topics:

- Occupant behavior and wellbeing
- Equity and sufficiency of buildings
- Human-centric building re(design)
- Human-centric building operations

List of In-Person Participants - Annex 95 - Seville Meeting

Acosta García, Dr. Ignacio

Andre, Dr. Maira

Abdelhadi, Dalal Omar

Abuimara, Dr. Tareq

Agee, Dr. Philip

Akele, Christina Maria

Alnajjar, Sonia Fayez

Andersen, Dr. Rune Korsholm

Andrews, Dr. Abigail

Andrews, Prof. Clinton

Arakawa Martins, Dr. Larissa

Arpan, Prof. Laura

Azar, Dr. Elie

Babich, Dr. Francesco

Baborska-Narożny, Prof. Magdalena

Bavaresco, Dr. Mateus Vinícius

Berger, Dr. Christiane

Bustamante, Dr. Pedro

Campagna, Kevin

Campano, Dr. Miguel Ángel

Cao, Yuan

Cecchi, Prof. Valentina

Chatterjee, Dr. Arnab Chatterjee

Cheung, Dr. Toby

Chinazzo, Dr. Giorgia

Chiucchiù, Agnese

Chokwitthaya, Dr. Chanachok

Chong, Dr. Adrian

Chung, Dr. Daniel Haeyoung

Cooper, Dr. Natalia

Cox, Prof. Robert

Cui, Yanghao

De Simone, Prof. Marilena

Derbas, Dr. Ghadeer

Díaz, Dr. Muriel

Domínguez-Amarillo, Dr. Samuel

Du, Dr. Bowen

Duarte, Dr. Denise Helena Silva

Favero, Dr. Matteo

Fernández-Agüera, Dr. Jessica

Fernández-Agüera, Patricia

Flagner, Stefan

García, Guillermo

Gauthier, Dr. Stephanie

Ghahramani, Dr. Ali

Giraldo Vasquez, Dr. Natalia

Gosselin, Louis

Goubran, Dr. Sherif

Guerra Santin, Dr. Olivia

Gunay, Prof. Burak

Gupta, Akshit

Hellwig, Prof. Runa T.

Hoque, Dr. Simi

Hormazábal, Dr. Nina A.

Kane, Prof. Michael

Khovalyg, Dr. Dolaana

Kramer, Dr. Tobias

Linetska, Odel

loh, Kelly
Lozinsky, Dr. Cara
Luna Navarro, Dr. Alessandra
Ly, Cynthia
Lyu, Dr. Kun
Mahdavi, Prof. Ardeshir
Mainini, Prof. Andrea Giovanni
Maria Kostka
Milan, Maria Lynn
Miller, Prof. Clayton
Mino-Rodriguez, Dr. Isabel
Moujalled, Dr. Bassam
O'Brien, Prof. Liam
Ouf, Dr. Mohamed
Outcault, Dr. Sarah
Pallubinsky, Dr. Hannah
Palma Florido, Ana Victoria
Pasut, Prof. Wilmer
Pathak, Maharshi
Peng, Dr. Zhikai
Roaf, Susan
Roberts, Dr. Ben M.
Roaf, Prof. Susan
Rouleau, Jean
Rupp, Dr. Ricardo Forgiarini
Russell Black, Jamal
Sánchez-Muñoz, María
Sánchez Cordero, Antonio
Santos, Dr. Luis
Schumann, Mathieu
Schweiker, Prof. Marcel
Shahzad, Dr. Sally
Shamsaiee, Masood
Smektala, Marta
Soebarto, Prof. Veronica
Sommer, Til
Sonta, Prof. Andrew
Spiekman, Marleen
Stopps, Dr. Helen
Tahmasebi, Dr. Farhang
Tamas, Ruth
Tartarini, Dr. Federico
Teli, Despoina
Toledo, Dr. Linda
Tolone, Prof. Bill
Touchie, Dr. Marianne
Trépanier, Marie-Pier
Vahdat, Mahnaz
Vicente Gómez, Noelia
Villeneuve, Hannah S.
Weber, Gundula
Whittem, Vanessa Christine
Yildirim, Serra
Zaniboni, Luca
Zhang, Yufei
Gómez, David
Schuller, Christian
Zhou, Dr. Jenny
García, Guillermo