Building Simulation and Optimisation 2022

Book of Abstracts

Session 1: Energy

A Demand Response Implementation Case Study for Islanding of a Building

Yashima Jain, Prasad Vaidya, Amit Chandra, Gopikrishna A, Uthej D and Vismaya Paralkar

The power sector is experiencing challenges with a change in load shape from the demand and supply curves from increased penetration of distributed generation (DG) in the form of renewable energy technologies. Microgrids and technological approaches at the building level that respond to these challenges along with providing resilience in the case of grid failure need to be incorporated to strengthen conventional power networks. In this paper, we present a case study with successes and challenges in implementing an intelligent state-ofthe-art islanding use case in a 400 m2 mixed-use building. We developed a control system that includes an intelligent Demand Response to extend the critical operation of the building, when grid supply is unavailable, using predictions of battery charge and on-site solar PV generation. We present our findings from the performance testing and occupant feedback of this islanding use case. In future, we intend to use machine learning and calibrated models to further improve the predictions.

The Twelve Percent Effect - Improvements in evidence-based design towards net-zero building performance

Sreejith Jayaram, Suyashi Srivastava, Amanda Thounaojam, Janani Venkatesh, Yashima Jain and Gaurav Vakil

The building sector in India contributes to about one-fifth of the country's total CO2 emissions. At COP26, India has committed to achieving net-zero by 2070 (RMI India, 2021). Net-Zero Energy Buildings (NZEBs) can accelerate the pace at which India can achieve its net-zero goals. Since, approximately 70% of India's buildings for 2040 are yet to be built, these can be designed, built and operated as NZEBs. There is significant scarcity of workforce and lack of training in college curricula about NZEBs. Solar Decathlon India (SDI) competition addresses this by enabling student teams to learn and design real NZEBs. The participating teams were provided learning resources and Building Performance Simulation (BPS) tools. This paper reports on an analysis of the final submissions over two years to evaluate their ability produce evidence-based designs for their projects. A similar analysis after the first year's submissions revealed areas of weakness in the students' ability to provide evidence-based designs, and additional resources and training were provided to teams and faculty in the second year to improve BPS skills. We observed that 12% more teams who provided evidence for their designs in the second year. Evidence for daylighting strategies saw the largest increase of 37%, and natural ventilation strategies were next at 18% increase. This research identified areas where students were able to provide BPS based evidence and the interventions improved their ability to do that.

Examining the variation in daily and peak electricity use in urban Indian households by AC ownership

Rajat Gupta and Anu Antony

Recent forecasts reveal increase in air conditioning (AC) units in India contributing to increased electricity demand. This study conducts statistical analysis of time-series electricity data to examine variation in electricity use for 54 urban Indian households by AC ownership.

Mean annual electricity use in households with one AC, two AC and three or more AC units was 3,482kWh, 4,180kWh and 5,472kWh respectively. Peak period of electricity use commonly occurred from 9pm-3am ranging from 2kWh to 6kWh, indicating prevalence of AC usage during sleeping hours. Policies supporting demand response and incentivising peak shaving practices utilising smart meter data would be required in managing the rise in absolute and peak electricity demand..

Sustainable Retrofit Solutions for Decreasing Energy Consumption of a Residential Building in Tabriz, Iran

Saba Hajizadeh, Senem Seyis and Touraj Ashrafian

The rapid growth of Iran's population in the last four decades causes many residential buildings. Since Iran subsidizes energy costs as well as water and electricity tariffs, the energy is cheap in Iran and most buildings are not occupied with energy efficiency measures. Therefore, the number of conventional residential buildings are increasing. This study aims to retrofit a residential building in Tabriz, Iran to show the importance of sustainable retrofits for decreasing building energy consumption. For this purpose, a case study building (i.e., reference building) was modeled using Design Builder and PVSOL®. Four scenarios addressing sustainable retrofits were applied to decrease the energy consumption of this residential building. The results demonstrate that all four scenarios successfully decreased the building's total energy usage to 65%. Accordingly, this study contributes to the architecture, engineering, and construction (AEC) literature and industry by demonstrating the significance of sustainable retrofits to reduce building energy consumption and carbon emissions.

Energy Performance Assessment of Gas Boilers, Air Source Heat Pumps and Insulation Type Pairings in UK Dwellings

Cavan Manners, Siliang Yang and Michael White

Domestic heating through conventional means is responsible for 62% of carbon emissions in the UK’s built environment, which certainly will slow down and hinder the UK’s target of Net-Zero Carbon by 2050. Air Source Heat Pump (ASHP) is a promising way to heat homes with low carbon emissions. However, poorly insulated houses can limit the efficiency of ASHPs, and thus weaken the system performance especially during cold days. This paper assessed multiple design options of a typical UK dwelling with varying strategies of heating systems (gas boilers and ASHPs) and building fabric insulation pairings for reducing heating system carbon emissions and improving overall energy efficiency. Through IES VE energy modelling, it was found that the highest energy saving about 53% and 44% reduction of carbon emission can be achieved in the peak winter month (January) by means of well insulated building fabric in association with ASHP over gas boiler with the equivalent building insulation. The clear benefit of the adequately insulated dwelling was also apparent with a yearly mean 58% reduction in fabric heat loss against inadequate insulation. This paper contributes to the matters concerning the integrated effect of building insulation and low-impact heating systems on dwellings’ energy performance during heating season.

Session 2: Urban Studies

Optimization of an energy community in Switzerland

Michael Klaiber and Matthias Haase

In energy planning of districts, it is often unclear what energy supply options are available and what influence different technology options have, including demand reduction through energy renovation. Thus, the use of a simulation and optimization tools is explored in the planning process of a specific case study in Switzerland. Four different scenarios were developed and annual life cycle costs (LCC) as well as CO2 emissions, are proposed. The results of the respective scenarios are categorized and compared according to CO2 emissions and LCC. It becomes clear that for CO2 emissions, there is a large reduction potential (up to 90%) with different LCC.

Data driven investigation of thermal comfort in an informal settlement – a case of Mumbai

Divya Chaudhari and Namrata Dhamankar

Large pockets of informal settlements are a common sight, especially in emerging economies like India. The built environment of these informal settlements remains an area less explored. This research therefore aimed to investigate thermal comfort in typical urban informal settlements. Real time onsite monitoring of environmental parameters affecting thermal comfort for 2 houses in a selected settlement of Mumbai was done which led to an inference that roof element of the house receives maximum solar radiation. The two cases were then further simulated in Design Builder to understand the effect of solar radiation and heat gain through the roof which is exposed the most. The research further expanded to studying mitigation strategies by adopting multiple roof assemblies as retrofit solutions for these houses. These assemblies were studied keeping thermal conductance, ease of installation, strength and over workability and maintenance into consideration. The research reveals how an overall study of thermal comfort through a datadriven approach can assist stakeholders and authorities to develop design-guidelines and strategies for thermal comfort in informal settlements.

Simulating the built environment for another globally distributed species

Derek Mitchell

Simulating the built environment for a globally distributed and diverse species e.g. to cope with climate change, has particular challenges. These are explored here using honey bees (Apis Mellifera L), a vital pollinator of food crops worldwide, consisting of 24 subspecies that maintain close temperature and humidity control in a self-constructed or partly human constructed built environment. Honey bee thermofluid characteristics and their requirements of the structure are largely unknown.

To address this an open source i.e. FreeCAD (Riegel and Mayer, 2019) and OpenFOAM (Jasak, Jemcov and Tukovic, 2007), computational fluid dynamics (CFD) conjugate heat model was developed.

Results from the model demonstrate the power of CFD in investigating the interactions with their built environment of another species by showing significant variation in convection flow with different honey bee sub-species in differing distributions within the nest.

Towards a universal access to Urban Building Energy Modelling - The case of low-income, self-constructed houses in informal settlements in Lima, Peru

Argyris Oraiopoulos, Pamela Fennell, Shyam Amrith, Martin Wieser Rey, Ivan Korolija and Paul Ruyssevelt

By 2050 urban population is estimated to grow from 4 billion to almost 7 billion, with over 90% expected in the Global South, where development often takes place as unplanned informal settlements, with essential shortage of critical infrastructure. In processing some of the associated rising challenges, Urban Building Energy Models can play a key role. However, such models have had limited presence in this context, highlighting the inequalities in the representation of such communities in this field. This paper works towards addressing this gap and presents the development of an Urban Building Energy Modelling workflow for analysing the thermal comfort in a self-constructed, low-income housing neighbourhood in Lima, Peru, using an innovative approach, based largely on open source software, such as EnergyPlus, QGIS and Python. The results highlight that the compact and dense built form of the building blocks, can cause higher heat retention, especially in lower thermal zones and therefore result in high indoor temperatures for longer. Additionally, the poor thermal performance of the buildings' fabric, can cause hourly indoor temperatures to rise to critical levels, especially in higher thermal zones, which can have adverse impacts on the residents' health. This first step in understanding some of the key issues these communities are facing, is critical in the early assessment of future building retrofit decisions.

Tailoring demand-reduction strategies for communities in India – the CEDRI project

David Jenkins, Kumar Debnath, Sandhya Patidar, Olufolahan Osunmuyiwa, Benoit Couraud, Paraskevi Vatougiou and Peter McCallum

This paper summarises the CEDRI method for quantifying baseline and future energy demand of a community – using a case-study community in Tamil-Nadu. The overall method includes modules relating to: i) dynamic building simulation for projecting future scenarios, ii) Hidden Markov Models for characterising and synthesising high resolution demand profiles, iii) Distributed Network modelling for performance issues in the local energy system, iv) results of co-production and householder engagement to help understand existing energy use, and identify likely future trends.

Although the method is designed to be technology-agnostic, future scenarios are proposed to demonstrate the working of the model, and the kind of outputs and metrics that are achievable – and, crucially, why these might be useful to different actors and sectors involved with reducing energy demand in buildings.

The work demonstrates that, for such diverse communities as can be found in India, replicability of method is more important than replicability of results. Rather than extrapolating the results of single case-study communities for much larger regions, CEDRI establishes a robust method that is agile enough to cope with different data limitations, building stocks, and behavioural approaches to comfort. The project also demonstrates the ability of dynamic building simulation to be used in conjunction with empirical energy data, network models, and qualitative information relating to cooling behaviour in specific populations.

Developing an Open Access Plugin for Urban Building Energy Modelling in QGIS

Pamela Fennell, Arygios Oraiopoulos and Shyam Amrith

Urban Building Energy Modelling has gained increased recognition over the past years, with many research teams developing custom modelling suites that can be used for numerous applications. However, in many cases the licensing costs, lack of transparency, the reduced capabilities of selected computational methods as well as the necessity for advanced computing skills, have restricted the wider uptake and utilisation of various developed programmes, especially in regions of the Global South and more specifically in low- and middle-income countries in South America and Southern Asia.

This work presents the first stages in the development of a freely available, open-source tool, able to perform dynamic thermal simulations of a large number of buildings, using a state of the art modelling engine within a user-friendly interface. The novel SimStock plugin for QGIS is able to run multiple EnergyPlus simulations through a customised Python script, for large numbers of buildings, by supporting the viewing, editing and analysis of input and output data in geospatial format. A key feature of the tool is its ability to work with differing levels of detail in the required input data and therefore overcome a significant barrier to access for UBEMs in the Global South.

This paper outlines the approach and the key components of the tool and further presents its application on a case study, a densely populated building block in Lima, Peru. By bringing the latest developments in UBEM to the context of the Global South, this work contributes to the continuous efforts for improving the aspects of inclusiveness, transparency and reproducibility in this field.

Session 3: Case Studies

Investigation on the impact of occupant-centric design method applications on building energy efficiency and comfort – a case study

Zsofia Deme Belafi, Julia Simon and Edit Barna

Designed and actual energy use in buildings depend on various factors. Due to many decades of scientific research and innovation on building technology, construction quality, climate representation, advanced design tools and other non-human-related aspects, energy consumption in buildings started to decrease. However, the desired net zero energy consumption levels many times are far from reality. It was found that an essential component of buildings, humans, needs to be accounted for in a more thorough way during the design process of a building. Without understanding and appropriately representing building occupants and their needs in the design process, it seems impossible to estimate real, in-use energy consumption levels. In a recent research project, building design studios were surveyed in Hungary about the methods used to consider occupants during their design projects. It was found that only 83% of designers know the expected number of occupants in the buildings designed, occupancy schedules are given only to 36% of them. Thermal, acoustic, visual comfort and IAQ expectations of spaces are given to 53%, 33%, 36% and 42% of building projects respectively. According to the survey results, only 39% of designers use some kind of dynamic building simulations to support their energy efficiency calculations in Hungary. Recent research suggests that with a more occupant-centric design approach, with more information on future occupants of the building, not only energy efficiency but comfort levels and space use efficiency can be increased as well. This paper shows to what extent these parameters could be improved in case of a case study office building from Hungary. Our investigations compare the results of the locally widely used, traditional design methods to the case where occupant-centric design methods are used.

Calibrated model of an experimental building to test passive thermal comfort solutions for the Global South

Amanda Thouanojam, Prasad Vaidya, Gurneet Singh and Sanjay Prakash

India is the third largest carbon emitter in the Global South, with millions of people facing the threat of climate related impacts. Buildings currently account for about a third of its energy consumption, and the anticipated new construction presents a huge opportunity not just for climate mitigation but also to provide comfort and shelter in a rapidly changing climate. Designers and builders are innovating in several net-zero buildings, but beyond the annual or monthly energy consumption, detailed performance studies of such buildings are often not available. This paper presents the findings from a model calibration exercise for an experimental building in India that uses passive design techniques and has been built as a prototype to test several technologies and operation practices where the learning can be applied to a larger campus effort. Hourly data for one entire month with significant diurnal variation were used in the calibration of the Energy Plus model. While the ASHRAE Guideline 14 thresholds for Mean Bias Error (MBE) and Root Mean Squared Error (RMSE) were met (at 9% and 14% respectively) through the calibration process, several issues were uncovered during the calibration. These included: challenges with using the pyranometer radiation data in the Actual Meteorological Year (AMY) weather, because changing the Global Horizontal Radiation had no impact on the results; the importance of window operation for calibrating a model of a passive building; the inability of the MBE and RMSE to capture significant errors in the shape of the indoor temperature profiles; and the usefulness of the calibrated model in uncovering problems with the measured data. Beyond this, the rigor of the modelling effort instilled confidence in the executives who were making investment decisions for the larger campus, which enabled discussion on the Life Cycle Cost of the proposed systems against several baseline scenarios.

Evaluation of Wind Tower Effectiveness in Rammed Earth Building

Zeynep Örgev and Neslihan TÜrkmenoĞlu Bayraktar

Due to global warming, the cooling requirements increase even in locations with broad heating periods. The integration of passive cooling systems, especially in buildings and settlements in hot-dry climates, contributes to the decay of energy consumption. The selection of the appropriate material and determination of the application technique is a significant issue since passive cooling systems significantly affect energy performance. In the study, a hypothetical residential building, assumed to be built with the rammed earth technique in Diyarbakır with hot-dry climate characteristics, is used to evaluate the suitability of wind towers in terms of natural ventilation and thermal comfort performance.

Finishing with net-zero: A case study of the energy systems in an experimental building

Janani Venkatesh, Prasad Vaidya, Amanda Thounaojam, Amit Chandra, Sanjay Prakash, Yashima Jain and Vismaya Paralkar

Net-Zero Energy Buildings are crucial to addressing climate change in the building sector ((IEA), 2019) and catalysing India’s goal to achieve net-zero by 2070. An experimental building (EB) in Bengaluru is a testbed for technologies and approaches that can help optimize energy to achieve net-zero performance in other similar buildings. This paper provides a case study of the EB and discusses the evolution of its energy systems and whether the goal to remain net-zero was maintained through this evolution. Since continuous commissioning was not conducted, the evolution of the project requirements thwarted the net-zero goal. Addition of a high-power consuming lab and a kitchen increased the loads of the building and altered the way the power would be used. Post-construction studies emphasised the need for continuous monitoring and highlighted specific action items that could restore the EB to perform as net-zero.

An Assessment of Building Information Modelling (BIM) Usability in Architecture Practice in Lagos, Nigeria.

Edward Oladigbolu, Edikan Okon and Eldad Akpoterabor

The importance of building information modeling (BIM) in the execution of construction and infrastructure projects cannot be overstated as Nigeria advances technologically. Despite the advantages of BIM for the construction sector, nothing is known about how it will affect Nigerian architectural practices. This study's objective was to ascertain how BIM has affected architecture businesses in Lagos, Southwest Nigeria. The study looked at the degree of BIM awareness in architectural firms, the most popular BIM software packages, the parts of architectural work supported by BIM, and its advantages in architectural practice, among other things. A questionnaire survey of 100 architects in Lagos was used to gather the data, which descriptive statistics were then used to analyze. The findings indicate that architects in Lagos have a high level of understanding of BIM, and that Autodesk Revit Architecture, Graphisoft Archicad, and 3D studio Max are the most often utilized BIM software programs. The respondents utilized these software programs less for analysis and more for creating 2D drawings, 3D visualizations, architectural details, and modeling. The outcome also showed that the study area's architectural businesses were more productive overall thanks to the adoption of BIM. The report suggests that certain programs and policies be implemented by businesses, professional associations, and the government in order to increase the benefits of BIM in project delivery and encourage its widespread adoption in Nigeria.

Session 4: Modelling and Simulation Studies

Ranking the Thermal Caliber of Capacitive Building Envelopes Using Data Envelopment Analysis

Isha Rathore and Elangovan Rajasekar

Thermal response of building envelopes is driven by the thermal resistance, capacitance and configuration of the envelope. However, thermal capacity has been majorly neglected in the performance assessments of envelopes.

This study presents a novel approach for efficiency-based ranking of capacitive building envelopes using Data Envelopment Analysis (DEA). A thermodynamic Esp-r model of a residential building located in Ahmedabad, India is developed. Thermal performance of 27 envelopes of varying thermal capacity are ranked using DEA for four major orientations.

It is observed that capacitive envelopes exhibit higher thermal calibre in south and east exposed scenarios compared to north and west scenarios.

Comparative analysis of daylight levels in an office space considering standard overcast sky condition and measured CIE sky type of Gurugram, India

Rohit Thakur, Riya Malhotra and Ankit Bhalla

The research on radiation and sky conditions in India is still in its infancy. For the purpose of daylighting design, it is essential to predict the amount of daylight that will be present in an interior area throughout the year. This forecast for the presence of daylight is given as absolute or relative to external illumination. A sky luminance distribution model or data is necessary for both scenarios. The 15 sky brightness distributions that the CIE (International Commission on Illumination) established for its homogenous sky types are meant to represent the sky type at each place in the world throughout various seasons. The CIE 15 General Sky models have been used in India in the past to estimate daylight, but owing to a lack of data, the overcast sky condition is used instead, which doesn't produce reliable results. The 15 different sky types that make up the CIE Standard General Sky family of luminance distributions may be compared to the observed patterns of sky brightness. The root mean square errors (RMSE) approach is used to evaluate how well the proposed sky model represents the real sky circumstances. Additionally, the VELUX daylight visualizer software is used to run a box model daylight simulation in order to extract illuminance levels for a correlation study of observed CIE sky conditions with cloudy sky circumstances. A 54 square metre office space with a 25% window-to-wall area ratio (WWR%), transparent glass with a visible light transmittance (VLT) of 51%, and surfaces with surface reflectance of 21% for the floor, 74% for the ceiling, and 51% for the walls makes up the simulation base case. The illuminance analysis experienced by daylight simulation, taking into account observed sky conditions compared to overcast sky conditions on the analysis grid, is calculated to be 23% more correct in March and 42% more accurate in September based on the correlation analysis of the simulated data. As a result, it is confirmed that the calculated set of CIE design sky will be utilized to improve passive window design for sites inside the appropriate climate zones in order to achieve improved cost optimization through precise illuminance prediction.

Development of Reduced Order Thermal Network Models for Indian Wall Assemblies

Aashi Kansal and Elangovan Rajasekar

Thermal network models simplify yet realistically represent various thermodynamic processes associated with the building. They enable estimation of building energy demand with relatively less computational resources compared to conventional simulations. Researchers have attempted to establish the tradeoff between model accuracy and computational intensity. There is a need to develop validated thermal network models for different wall assemblies. This paper presents thermal network models for various Indian wall assemblies with different U values.

A thermal network model of a residential building is developed in open modelica and validated using real time data from a test bed located in Hyderabad, India. According to Koppen Gieger classification Hyderabad has tropical wet and dry climate. The building is a residential test bed having an area of 40 sqm. Thermal network models of Indian wall assemblies are developed as per VDI 6007 guidelines. The 3R2C model of bedroom yields a MAE (Mean Absolute Error) value of 0.76 ˚C. The effect of model order reduction (5C, 4C, 3C, 2C) on prediction accuracy is discussed.

RoofKIT – Building simulation in sustainable housing at the Solar Decathlon Europe 21/22

Nicolas Carbonare, Moritz Bühler, Jens Pfafferott and Andreas Wagner

The contribution of the RoofKIT student team to the SDE 21/22 competition is the extension of an existing cafe in Wuppertal, Germany, to create new functions and living space for the building with simultaneous energetic upgrading. A demonstration unit is built representing a small cut-out of this extension. The developed energy concept was thoroughly simulated by the student team in seminars using Modelica. The system uses mainly solar energy via PVT collectors as the heat source for a brine-water heat pump (space heating and hot water). Energy storage (thermal and electrical) is installed to decouple generation and consumption. Simulation results confirm that carbon neutrality is achieved for the building operation, consuming and generating around 60 kWh/m2a.

Performance evaluation of Phase Change Materials for cooling Photovoltaics and enhancing efficiency

Sanober Khattak, Shivangi Sharma and Siliang Yang

Despite the carbon reduction potential of Photovoltaics (PV) for buildings energy use, its adoption in the residential sector is limited. For effective building integration, it is crucial that PV panels operate close to the standard conditions (~25°C). Overheating of PV in hot climates leads to low PV efficiencies, which can adversely affect the technology adoption. In this study, the effectiveness of Phase Change Materials (PCM) in reducing panel surface temperatures of Concentrated Photovoltaic (CPV) in the Global South (GS) is explored. Utilising lab-based experimental data from a CPV-PCM system, and a co-simulation approach using the software BCVTB, MATLAB (v2018b) and EnergyPlus (v8.8), the panel surface temperature and CPV efficiency were simulated. A total of 128 locations across 17 countries in the GS were identified for simulation that satisfied the following conditions: (i) EnergyPlus weather files (.epw) availability, (ii) yearly averaged diurnal swing greater than 10°C, and (iii) peak summer temperature in excess of 25°C. From the results, we identified 36 locations in the GS where PCM integrated PV resulted in a 2% - 7% relatively improved annual average efficiency over the non-PCM baseline, while in the remaining 92 locations PCMs either did not make a notable improvement or reduced the efficiency.

Session 5: IEQ

Occupant Behaviours and Environmental Preferences in Home-Office Environments Versus Conventional Office Environments; Reflections from The Pandemic.

Barah Rababa and Eleni Ampatzi

This paper focuses on differences in thermal comfort perceptions and behaviours between home-based and conventional office settings and discusses the consequences of its findings on domestic energy use in the UK in the context of extreme circumstances and beyond. Data were collected using a web-based questionnaire and online follow-up interviews. The 106 responses to the questionnaire captured the frequency of some adaptive behaviours. The in-depth interviews revealed a wide range and diverse adaptation strategies that people exercise when working from home, while these coping strategies were very limited in conventional offices. The findings of this study indicate that occupants were satisfied with working from home, and the main elements they prefer for a future home office are energy-efficient airtight windows and good ventilation. Participants tended to apply low-cost strategies, related to the heating routine and practices. Further research could usefully propose an energy-efficient home office with the technological and personal behaviours and the upgraded standards revealed in this study.

Evaluating indoor environmental quality of onsite construction workers housing in Pune, India through performance-based simulation

Sayali Andhare and Namrata Dhamankar

Construction workers are the city's most essential service providers, but their contribution to the urban economy is frequently overlooked. Most construction workers are migrants, and the primary reason for their migration is to find suitable job opportunities and an improved living standard. Whether the growth of the infrastructure sector raises the standard of life of migrant workers is a matter of concern since these migrant workers frequently relocate every few years to other places living in temporary constructions near or on the job site provided by the owner or a contractor. This research examines the indoor environmental quality of onsite housing for construction workers. It presents a part of the ongoing research assessing the parameters that impact the onsite housing system for construction workers in terms of building materials, services provided, and indoor environmental comfort. Simulation studies were carried out to analyse the annual performance. In addition, the performance of various materials was evaluated along with daylight and ventilation analysis throughout the year. The research's main findings are that onsite workers living in a modular prefabricated system can achieve indoor environmental comfort by using a wall panelling system made of paper honeycomb sandwiched between powdercoated G.I. sheets can provide thermal comfort with additional aluminium bubble wrap insulation for the roof. Eco coolers, a passive cooling system, are also used to improve the ventilation inside the unit. This system provides thermal insulation while also being affordable and scalable for the temporary housing category.

The impact of built environment on thermal comfort in informal settlements. The case of José Carlos Mariátegui, Lima, Perú.

Martin Wieser, Marion Verdiere and Pamela Fennell

Building energy simulation is little used in Lima, Perú where the generally mild climate means little energy is used for space heating and cooling. This study is the first attempt to explore thermal comfort for marginalised communities living in self-built accommodation and finds a significant thermal comfort gap largely driven by inadequacies in building materials. To carry out the necessary measurements, a meteorological station and 15 data loggers were installed in 3 archetypes identified in the study neighbourhood. The clear link between building materials and internal conditions suggests an important role for urban building energy simulation to enable communities with severely constrained resources to explore the impact of different interventions.

Impact of Green Building on Productivity of Offices

Kshitij Kacker, Abhijit Rastogi and Virendra Kumar Paul

Green buildings certifications claim that it can improve the productivity of employees in a workplace. India service sector is a key driver of economy. With the growing mandate of applying green buildings norms in Indian buildings, there is no such analysis that could tell the affects. As there is no exact methodology to calculate productivity, this study uses real time data collection, through questionnaire surveys and instruments to get a self-assessed perception of the architecture employees in the offices in composite climate of India and using a multiple linear regression model for the comparison. The results show an improvement in the relative productivity by 38.96%. The study, can be used as a base for understanding aspects of IEQ in the workplace productivity in Indian conditions.

Quantifying the effect of roof insulation on indoor comfort and cooling loads in Nigerian residences

Henry Odiri Igugu and Jacques Laubscher

Nigerian urban residences largely depend on energy intensive mechanical techniques to achieve a temperate indoor climate. Mechanical devices are powered with electricity from fossil-fuelled power stations. However, roof insulation as an effective passive measure of lowering indoor cooling loads is not standard construction practice in Nigeria. This study assesses the efficiency of using Extruded Polystyrene (XPS), Glass wool and Spray Polyurethane Foam (SPF) roof insulation materials to reduce annual cooling loads while maintaining optimum indoor thermal conditions. Using the Lagos metropolis as a case study, the dynamic simulations indicate improved comfort levels with cooling load reductions of approximately 7%-8% under an annual average outside dry-bulb temperature of 27.4oC and an ASHRAE recommended indoor temperature setpoint of 22oC. Furthermore, the results suggest an optimum roof insulation R-value range of 2.5m2K/W to 3.0m2K/W. Including insulation as part of the roof construction could alleviate the challenge of increased energy consumption in Nigeria's rapidly growing residential building population while reducing the GHG and Carbon emissions during its operational lifetime.

Session 6: Machine Learning & Optimisation

Multi-agent learning of incremental housing development strategies for solar utilisation in Peru

Sergio Edgar Mauricio Poco-Aguilar, Darren Robinson and Parag S Wate

Incremental housing, whereby an initial core unit is constructed and occupied by a family, who then progressively enlarge it during its lifetime, is a common form of housing provision in Peru, and many other countries in the Global South. However, these complex enlargement decisions, which place a significant financial burden on homeowners, are likely to be sub-optimal in terms of energy and cost effectiveness. To address this, we have developed a new computational workflow, combining geometry generation, multi-agent reinforcement learning and energy modelling to support incremental housing owners to optimise their enlargement decisions. In this paper, we describe this new prototypical workflow and its application to two use cases: a single housing unit, surrounded by a static neighbouring scene and a single housing unit that dynamically interacts with a changing neighbouring scene. In both cases, we arrive at stable solution that maximise solar energy availability at least cost.

Optimisation of passive design implementations at an urban scale in an Am climate zone

Nicholas Swedberg

This paper utilised Chattogram, Bangladesh, as a case study city in an Am climate zone, a typology found throughout the Global South, in order to test the ability of passive design measures to mitigate the formation of the urban heat island and the resultant impact on the urban dwellers of Chattogram. Cities in hot-humid climates represent and understudied typology, and given the rapid population growth of Chattogram, careful consideration needs to be given to urban development in the city. This study utilised open-source tools and data to create a workflow for testing these passive measures. The study found that, while effective in reducing dry bulb temperatures in the case study city, the impacts of high humidity meant that some health and well-being risk were not neutralised to as great an extent.

A Modular Thermal Space Coupling Approach for Indoor Temperature Forecasting Using Artificial Neural Networks

Jakob Bjørnskov and Muhyiddine Jradi

With the increasing digitalization of buildings and the adoption of comprehensive sensing and metering networks, the concept of building digital twins is emerging as a key component in future smart and energy-efficient buildings. Such digital twins enable the use of flexible and adaptable data-driven models to provide services such as automated performance monitoring and model-based operational planning in buildings. In this context, accurate indoor temperature models are vital to ensure that the proposed operational strategies are effective, feasible, and do not compromise indoor comfort. In this work, the significance of thermal space coupling for data-driven indoor temperature forecasting is investigated by assessing and comparing the performance of an isolated and coupled Long Short-Term Memory model architecture across 70 spaces in a case study building. To construct the coupled architecture, an open-source tool is developed and presented, which allows the automated extraction of space topology from IFC-files to identify adjacent spaces. The coupled architecture is

found to outperform the isolated architecture for ~84% of the investigated spaces, with significant improvements under certain operational and climatic conditions. To account for the subset of spaces where the isolated architecture performs better, it is proposed to select between the two architectures accordingly. The demonstrated modularity and embedded adaptability of the proposed model architectures provide a sound basis for implementation in a highly dynamic building Digital Twin environment.

Using a system dynamics framework to develop a decision-making model for Building Energy Efficiency Codes in the Global South

Tariené Gaum, Henry Odiri Igugu and Jacques Laubscher

Building energy efficiency codes (BEECs) remains the basis for optimised and contextualised building simulation. Thus, the lack of BEECs in 28 out of the identified 57 Global South (GS) countries hinders the optimisation of building design and simulation in the GS. This paper uses a system dynamics (SD) approach to develop and present a framework to structure and compare BEECs. The synthesis of the structure of Global North (GN) models with the determined hierarchy of built elements in the mandatory BEECs of 19 GS countries results in a proposed GS model. Ultimately, the resulting model is applied to develop a Sustainable Levels Indicators Matrix, Model and Maps (SLIM3) as an interactive online decision-making tool.

Predicting Operative Temperature with Machine Learning (ML)

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With climate change, low carbon space-cooling approaches are becoming more important. Cooling energy demand can be reduced through new interventions, low energy systems, and optimised operation. The adaptive comfort model for mixed mode operation can be a promising approach to the cooling energy challenge. However, adaptive models use indoor operative temperature, which requires the measurement of air temperature, air velocity, and globe temperature in a space. Collecting real-time and long-term data for these is difficult.

This paper summarizes a study on an affordable cooling approach to develop a machine learning algorithm to predict OT. Field measurements and Energy Plus simulation were used to create large datasets, 75 % of which were used to train the machine learning algorithm to predict operating temperature, and the remaining 25% were used for testing the algorithm.

The testing of the OT predicted with the random forest model shows an RMSE of 0.34%. In terms of classification of the thermal environment as being in/out of the adaptive comfort band, 0.88% of values were misclassified. When the predicted OT values were compared with the one-week measured OT values, the RMSE was found to be 3%.

The results demonstrate that our algorithm that uses indoor air temperature readings in a space and outdoor weather station data can reliably predict OT. This enables a scalable and affordable approach for accurate and long-term prediction of OT to determine the comfort condition.

This will enable control systems to use OT to determine thermal comfort in a space using adaptive comfort models and to account for ceiling fan usage to reduce or eliminate air-conditioning (AC).