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SinBerBEST

Ceiling Fan Application in Singapore

Stefano Schiavon and Toby Cheung

Reducing air conditioning (AC) reliance is becoming increasingly important due to the growing population in tropical countries. It is predicted that 60% of the world's population will live in these countries by 2060, up from 40% in 2008. This shift, along with the economic growth in these regions, may lead to a subsequent increase in the number of AC systems that will be in use. The International Energy Agency has predicted that as many as four billion additional AC units are expected to be in operation by 2050. In other words, 10 new units will be sold in every second for the next 30 years.

Ceiling Fans Performance on Building Occupants

Many commercial buildings in the tropical climates are overcooled, causing energy waste and occupant dissatisfaction. This problem can be solved by increasing the indoor air temperature, and simultaneously increasing the air movement with fans as needed. This simple solution can enhance the thermal satisfaction of the occupants as they prefer air movement to still air, and have direct control of the environment. Also, this option can provide substantial energy savings. Our energy analysis for tropical buildings have shown that up to 45% mechanical energy savings can be achieved by increasing the cooling temperature setpoint (Figure 1).

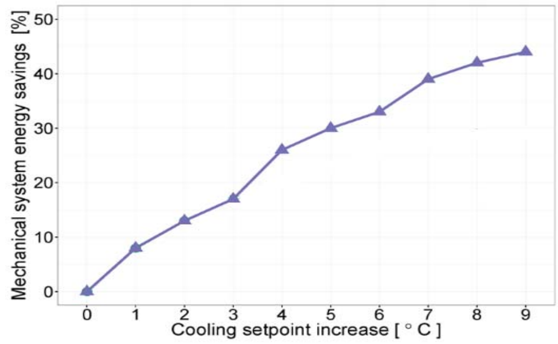

FIGURE 1 Mechanical Energy Savings Gained by Increasing Cooling Setpoint.

First, we demonstrated the ceiling fans' impact on human comfort, satisfaction and performance in a laboratory with 56 Singaporean subjects. Subjects were exposed to five conditions: 23°C without occupant-controlled fan, 26°C with occupant-controlled fan, 26°C without occupant-controlled fan, 29°C with occupant-controlled fan, and 29°C without occupant-controlled fan (Figure 2). We found that the occupants' thermal comfort, their perceived air quality, and sick building syndrome symptoms are equal or better at 26°C and 29°C than at the common setpoint of 23°C if personally-controlled fans are available for use. The best cognitive performance (as indicated by task speed) was obtained at 26°C. At 29°C, an occupant-controlled fan partially mitigated the negative effect of the higher temperature.

Then, we conducted a field study that involved white-collar workers in a Singapore office to examine the impact of increased room temperature and air movement on these workers' thermal comfort and their self-reported productivity. Compared to a 23°C setpoint, a room's temperature can be increased to 27°C without negatively affecting the occupants' thermal satisfaction when user-controlled air movement is provided (Figure 3). Also, occupants are more satisfied while operating fans at 26°C than they were while not operating fans at the typical 23°C. Further, the higher temperature reduced the relative humidity from 62% at 23°C to 50% at 27°C.

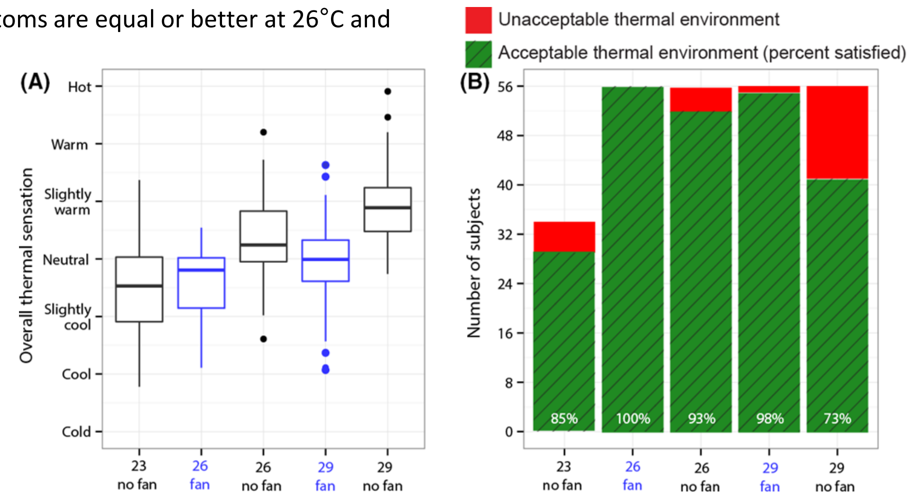

FIGURE 2 (A) Overall Thermal Sensation and (B) Overall Thermal Acceptability for the Five Tested Conditions. Fan Conditions Are Highlighted In Blue.

The results showed that occupants preferred an office environment at 26°C with fan operation (as 78% occupants wanted "no change" in thermal preference,) over the typical overcooled environment at 23°C setpoint without fan operation (as 63% of occupants wanted "warmer" temperature at workstations.) As shown in Figure 4, while occupants tended to report a "slightly cool" sensation at 23°C, they indicated a "neutral" sensation when the air temperature was increased to 26°C and a ceiling fan was in use.

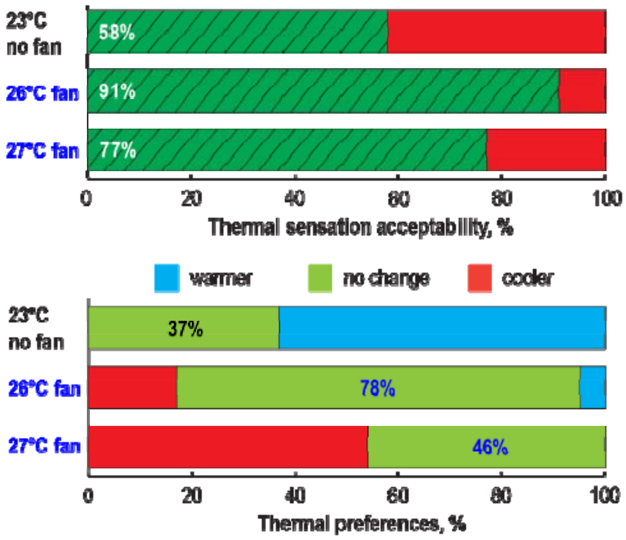

FIGURE 3 Thermal Environment Acceptability and Preference Regarding Thermal Sensation

Interestingly, occupants' self-reported ability to concentrate, to be productive, and to be alert was comparably high in all conditions. Although the findings showed that the occupants' work performance is poorly correlated with the room's temperature, it may increase with higher personal thermal satisfaction. This suggests that in tropical countries, occupant's self-reported working productivity is not enhanced by lower temperature, but it is dependent on the overall thermal conditions with high thermal sensation acceptability at workplaces.

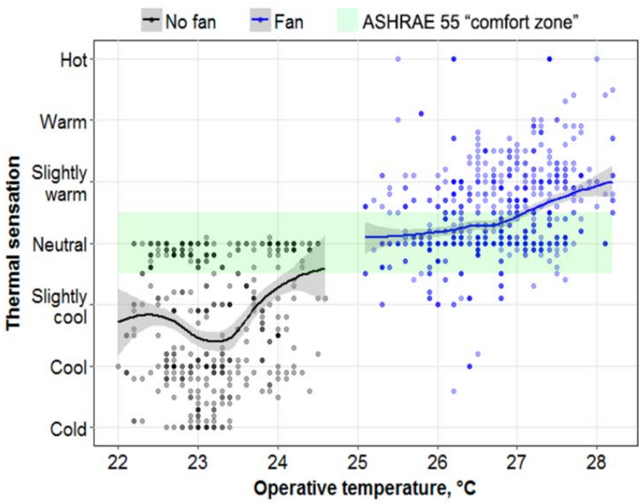

FIGURE 4 Thermal Sensation Correlated with Operative Temperature at Workstations

Ceiling Fan Performance on Airflow Profiles

There are limited data and tools to support fan design and control, especially for multiple-fans. Designers do not have enough information about the airflow patterns created by fans. We examined airflow profiles generated by both single-fan and multiple-fans cases using high spatial resolution air speed measurements (5,760 and 20,160 measuring points for the two cases respectively) in a climatic chamber. Then, we evaluated typical airflow patterns from the measurements and validated them using smoke visualization. This is the first time that the multiple fan interaction has been studied.

The single-fan study findings showed that the air speed was high under the fan and at the floor (or desk), but it was low outside its zone of influence. This is similar to the effects of water falling from a ceiling shower head. A single-fan usage causes a lack of air speed homogeneity in the space. To overcome this problem, multiple-fans can be deployed and arranged in close proximity (Figure 5). This fan study data will help designers and building owners to create an optimal comfortable and energy-efficient environment

User-friendly single-fan and multiple-fan air speed measurements visualizations has been developed and can be accessed online (Single fan: https://cbe-berkeley.shinyapps.io/single-fan/ ; Multiple fans: https://cbe-berkeley.shinyapps.io/two-fans/). Results obtained from this tool can be used to validate CFD models and help optimize fan layout design. An example for single-fan interface is shown in Figure 6. All the measurement results and the visualization tools are available to the public (open source).

Summary

Our findings demonstrate the significant opportunity for using ceiling fans to increase occupant thermal satisfaction and comfort, while reducing energy consumption and greenhouse gas emissions. Higher occupant thermal comfort satisfaction can be obtained at increased temperature (26°C and 27°C) with ceiling fans than at the typical temperature setpoint 23°C, with no change in occupants' self-reported productivity, concentration, or alertness. The laboratory results from this approach has been successfully validated in a Singapore office.

In addition, we studied the air speed patterns for single- and multiple- fans cases. For the single-fan case, the fan jet shape was centralized only under the blade area, which may cause non-homogeneous air movement. For the multiple-fan case, fans can be arranged in close proximity to optimize air flow patterns in the space. A user-friendly online visualization tool based on our measurements has been developed for researchers and designers.

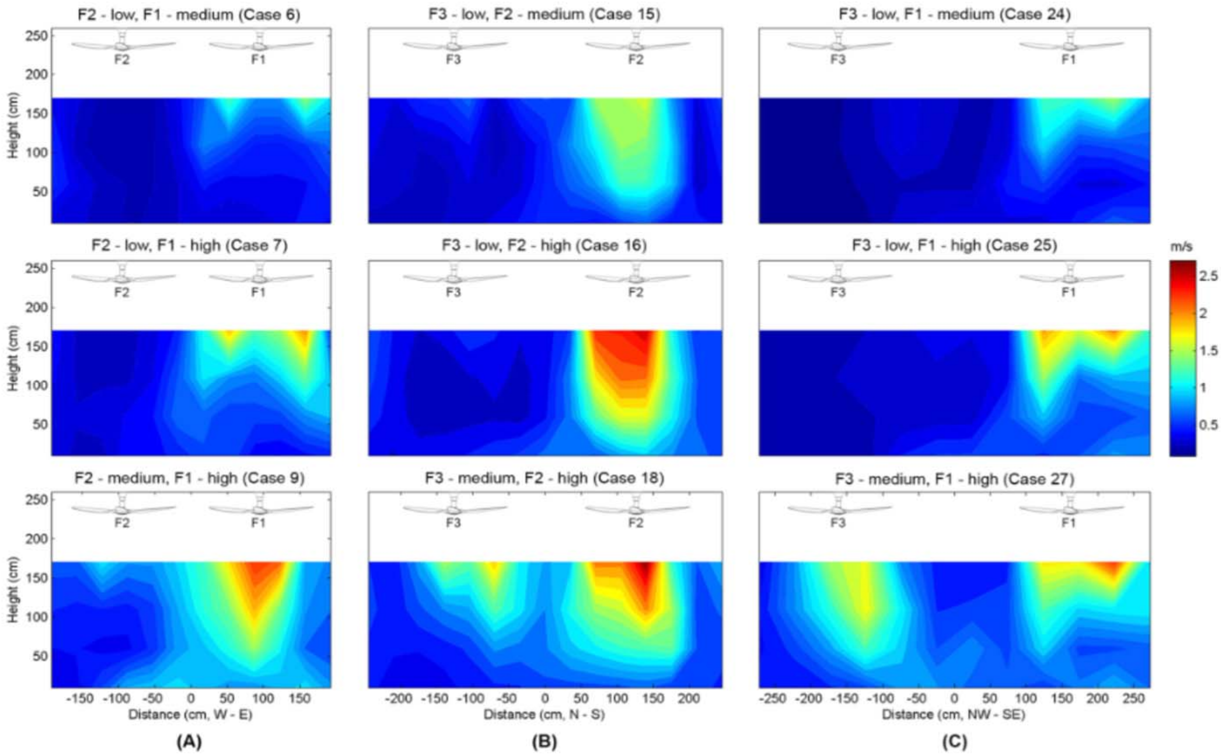

FIGURE 5 (A) Overall Thermal Sensation and (B) Overall Thermal Acceptability for the Five Tested Conditions. Fan Conditions Are Highlighted In Blue.

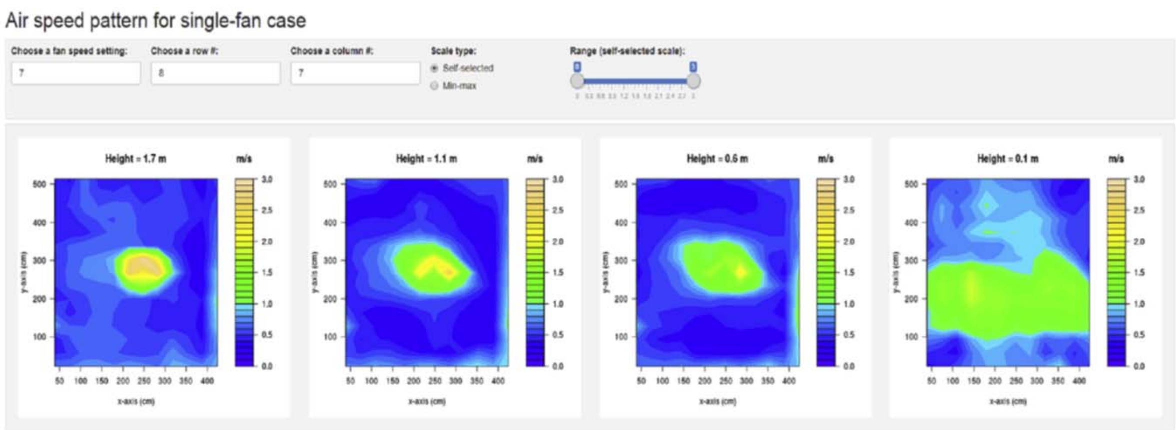

FIGURE 6 Airspeed visualization tool interface (single-fan)

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Schiavon S, Yang B, Donner Y, Chang VW, Nazaroff WW. 2017. Thermal comfort, perceived air quality, and cognitive performance when personally controlled air movement is used by tropically acclimatized persons. Indoor Air, 27(3):690-702. doi: 10.1111/ina.12352.

Lipczynska, A., S. Schiavon, and L. Graham. 2018. Thermal comfort and self-reported productivity in an office with ceiling fans in the tropics. Building and Environment, 135, 202-212. doi: 10.1016/j.buildenv.2018.03.013

Liu S., Lipczynska A., Schiavon S., Arens E. 2018. Detailed experimental investigation of air speed field induced by ceiling fans. Building and Environment, 142, 342-360. doi: 10.1016/j.buildenv.2018.06.037

ASHRAE Global Thermal Comfort Database II

Toby Cheung and Stefano Schiavon

A new suite of free and publicly available online resources have been launched to facilitate academic and professional studies of thermal comfort in buildings, the result of a four-year effort led by the Center for the Built Environment at UC Berkeley and the University of Sydney's Indoor Environmental Quality Laboratory.

These tools can be used to inform questions about thermal comfort, and to encourage the design of climate-responsive and comfortable low and zero energy buildings. At SinBerBEST, Dr. Cheung lead the development of an interactive visualization tool and Dr. Parkinson, previously at UoS and now supported by SinBerBEST, developed a tool to access and query the thermal comfort data collected from field studies from around the world. This work serves a fundamental goal of SinBerBEST's research consortium: to make key research findings available to industry and to provide 'actionable insights' that improve building design and operation. The project is described in detail in a recent article and granted the best paper award 2018 in Building and Environment (out of 3000 submissions, and 640 published papers).

The database holds findings from research conducted over two decades, created in collaboration with over 60 contributors around the world who released their raw data for wide dissemination (Figure 1). The research team collected over 107,000 rows of data, pairing subjective 'right-here-right-now' comfort responses with environmental measurements relevant to thermal comfort. In addition to being an impressive body of collaborative data collection (the largest thermal comfort database to date), the project team strove to build resources for both industry practitioners and researchers.

Interactive Visualization Tool

The visualization tool is a powerful and user-friendly interface for researchers and practitioners to explore and navigate their way around the large volume of data. The interface is divided into three pages to examine satisfaction scores, adaptive comfort, and other variables, using preset boxplots, bar charts and scatter plots that enable rapid data visualization and analysis. An example of the interface is shown in Figure 2.

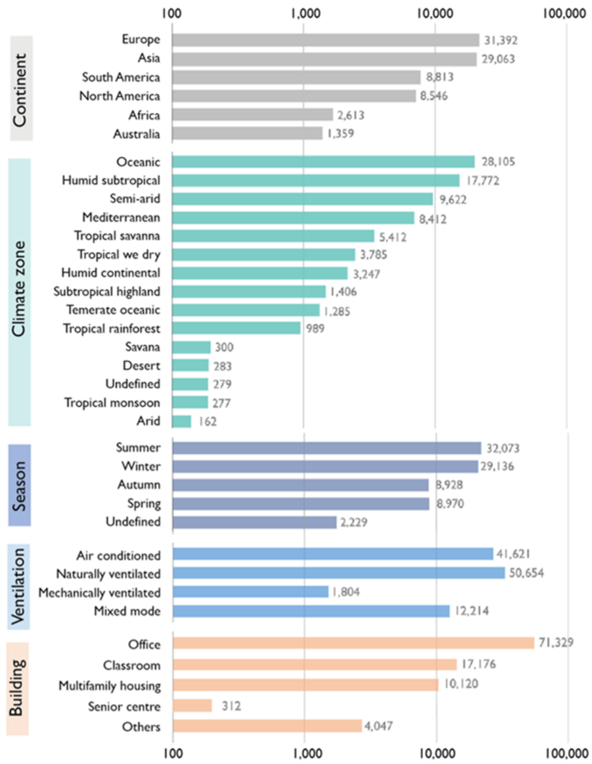


FIGURE 1 Distribution of Thermal Comfort Data by Categories

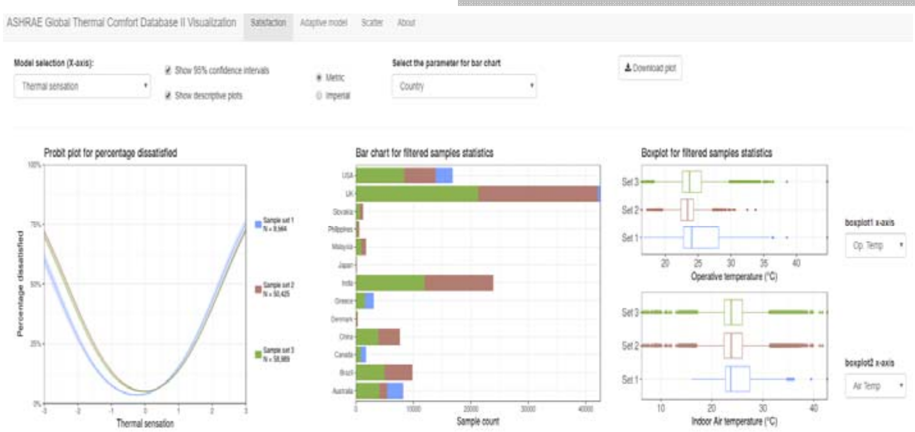


FIGURE 2 Thermal Comfort Database Visualization Tool Interface

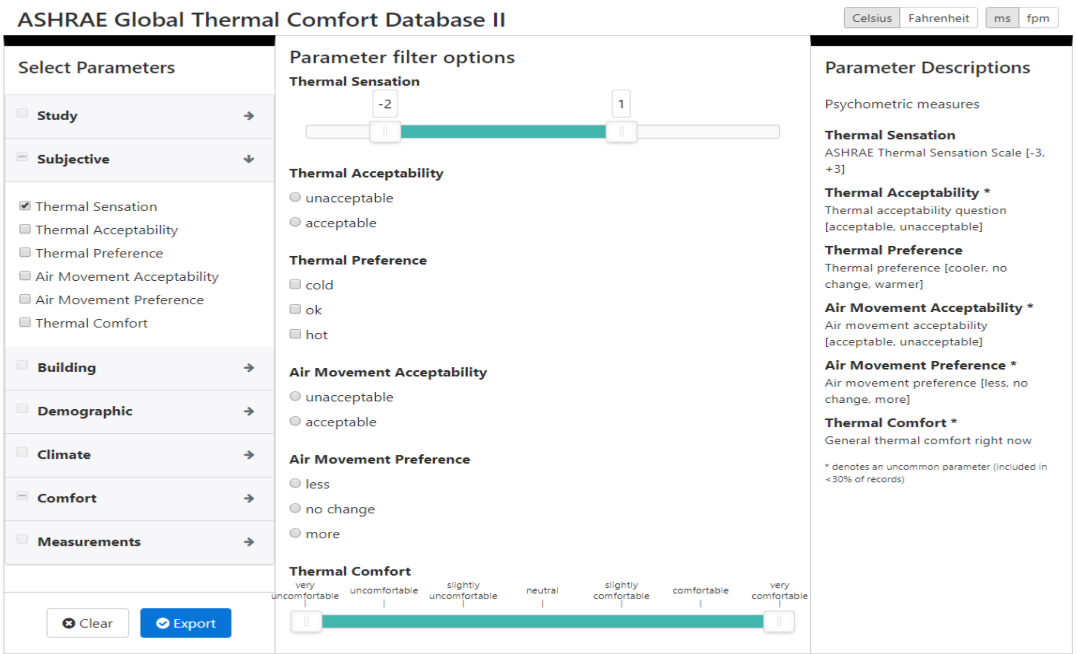


FIGURE 3 Query Builder Download Interface

Query Builder

Design practitioners and others who are more proficient in Excel or other numeric/statistical software can perform their own analyses by downloading the full database, or a subset of the data. The query builder enables filtering of the data on multiple criteria, including building and occupancy type, climate, demographic variables, subjective thermal comfort states, indoor thermal conditions, and many other variables. Results can then be downloaded in a generic comma-separated-values (csv) file.

These tools were created to inform a diverse range of both design and research questions. For example, someone looking to understand comfort temperature limits when designing a mixed mode-building could use the database to inform set point control options based on field-acquired occupant comfort votes, rather than laboratory-based suggestions found within a guideline or standard. Or an engineer tasked with specifying elevated air velocities in offices (e.g., for fans) could use the database to analyze acceptable velocities at given air temperatures. The database also contains data from different building types, such as homes or schools, contexts for which guidelines are difficult to find.

Reference

Földváry Ličina, V., Cheung, T., Zhang, H., de Dear, R., Parkinson, T., Arens, E., Chun, C., Schiavon, S., Luo, M., Brager, G., Li, P., et al. 2018. Development of the ASHRAE Global Thermal Comfort Database II. Build. Environ. 142, 502–512. https://doi.org/10.1016/j.buildenv.2018.06.022

Link to visualization tool

Link to query builder

Grid-Edge Technologies for Smart Buildings

Sanjib Panda

The rise of distributed renewable energy resources such as solar, wind, etc. is disrupting traditional structures of power generation and delivery. This enables end-users of electricity such as buildings to become "prosumers" by generating, storing, and selling their own power. New technologies and business models are allowing them to create new types of building-to-building and building-to-grid interactions on a two-way grid through bi-directional power flow and services. Grid-edge technologies, solutions and business models, advance the transition towards a decentralized, distributed, and transactive electric grid.

At grid-edge, building operators will be empowered to become active participants in this new electric grid. Smart buildings contain diverse energy resources including storage devices, renewable energy sources such as photovoltaic generation, and critical/non-critical loads. In SBB1.0, we developed the concept of an energy node (representing a smart building) as shown in Figure 1 with hybrid AC and DC distribution networks within building.

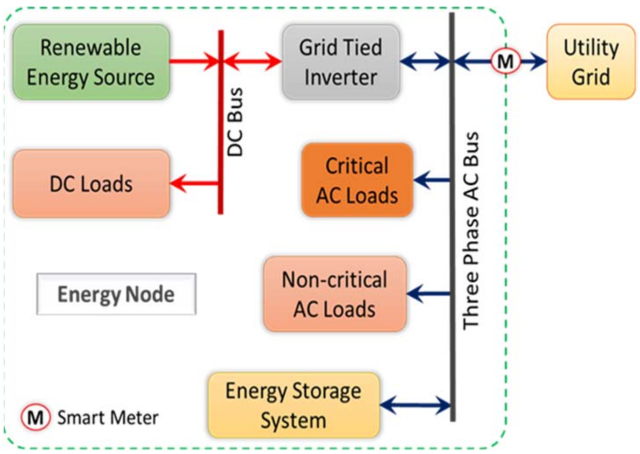


FIGURE 1 Hybrid AC and DC Distribution Networks Within Building

Campuses, industrial parks, and communities of buildings at district level can share distributed resources to enhance their collective efficiency, resiliency, and sustainability through integration of multiple energy-nodes to form a micro-grid. This micro-grid structure may be as shown in Figure 2.

This platform is scalable enabling community of buildings to share resources through "energy nodes", and for buildings to interact with the utility grid to produce and monetize value-added services. As a result, aggregations of smart buildings can cooperatively manage their collective resources enabling greater energy efficiencies. The suite of topics explored for this platform is represented in Figure 3.

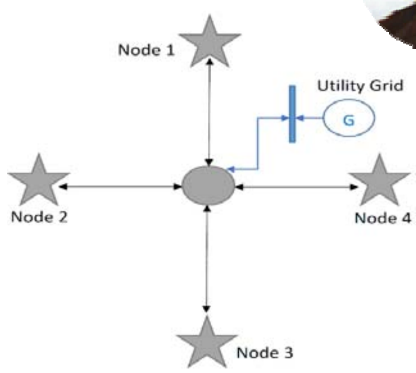


FIGURE 2 Integration of Energy Nodes

The research challenges involve active coordination of resources across buildings, efficient distribution and usage of resources locally that require communication infrastructure and the design of distributed coordinated control systems.

Transactive Energy Framework based aggregation capability is being designed and incorporated into our energy-node platform for distributed and scalable control strategies for demand side management. Transactive energy (TE) is defined as "a system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter". The "value" here refers to the economic or engineering value (such as profit, comfort or performance) that is associated with a transaction. Transactive control of building resources would include local-decisions and two-way communications which lead to full use of demand response potential, management of privacy issues, and certain system reaction to grid operator signals. The energy-node platform can also serve to provide building-to-grid services that support a city-scale sustainability agenda. SSB2.0 Theme-B Area-3 explores the role of grid-edge energy node clusters in displacing spinning/non-spinning/contingency reserves as well as other ancillary service provisions, such as regulation and load balancing.

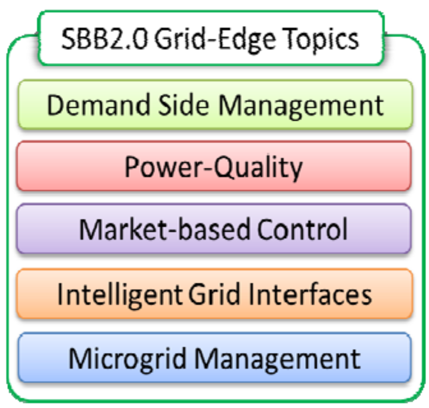
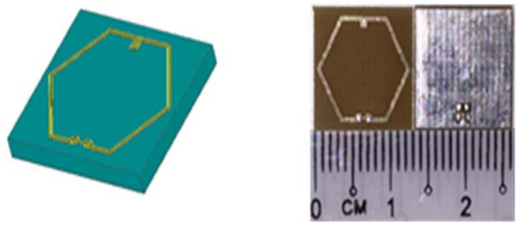


FIGURE 3 Grid-edge Technologies for Smart Buildings as Energy Nodes

Electrically Small Metaresonator Antenna for Sensors in Buildings

Sum Yee Loon, Vanessa Rheinheimer, Soong Boon Hee, Paulo J.M. Monteiro

The aim of this current project is to design and develop an antenna for wireless sensors with two main goals: a) To facilitate wireless communications; and b) to allow for RF energy harvesting, especially for embedded sensors in building materials.

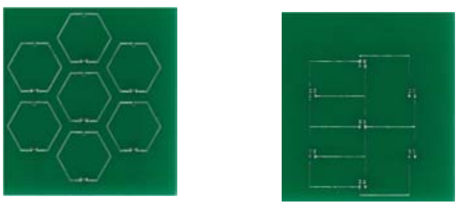


A B

FIGURE 1 Electrically small metaresonator antenna (A) perspective view (B) fabricated front (left) and back (right)

The unit element antenna design (Figure 1) is inspired by metamaterials use of SRR (split ring resonator) to form a LC resonant circuit to reduce the size of antennas. This enables the design of electrically small antenna with a maximum dimension of one-tenth the operating wavelength with the constraints of a) using standard PCB (printed circuit board) technologies, b) cost effective PCB material of FR-4, and c) planar in structure.

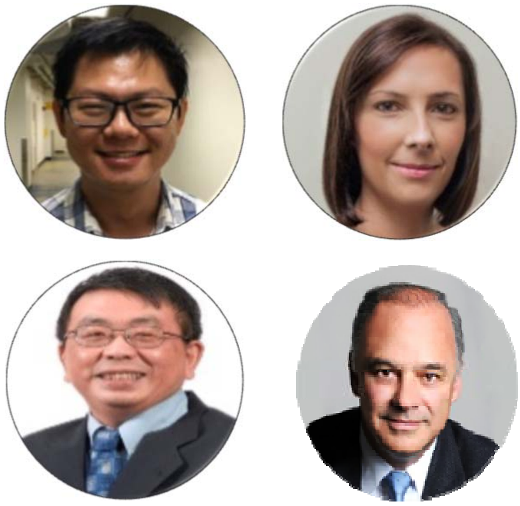
The resulting antenna has its impedance well matched at the desired frequency of 2.45 GHz without any matching circuit. This is made possible by the stubbed design that can adjust in length to tune the antenna to the frequency that is desired.



A B

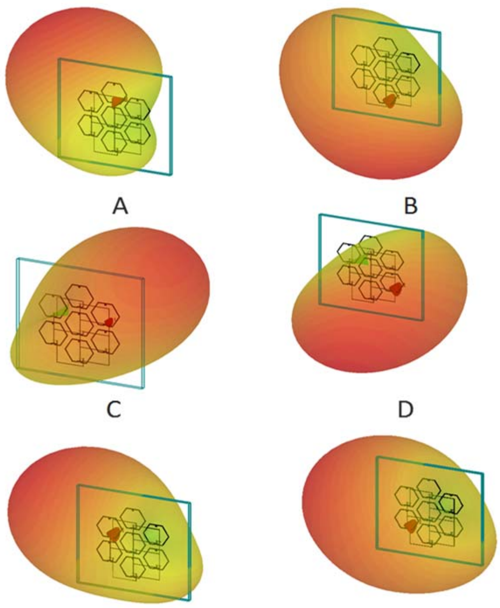
FIGURE 2 Possible metaresonator array: (A) front view (B) back view

Another useful feature of this antenna design is the hexagonal shape. This shape allows each antenna to function as an antenna array element to form into a scalable array. As a result of designing each metaresonator antenna with a maximum dimension of one-tenth the operating wavelength, it is also considered a unit cell in a metamaterial. With this consideration, each unit element can be arranged closer to each other, increasing the area utilization as compared to conventional antenna arrays. Figure 2 shows one possible arrangement of such a scalable array.



The length of the stubs of each element can be adjusted to fine-tune the array to resonate at the desired frequency as the array scales.

Scalability provides the necessary freedom to adjust the size of the antenna array to conform to different surface areas in a built environment, as well as the amount of RF energy that can be harvested. By feeding the array at different locations, it can also be made to point in different directions in cases such as pointing to a RF source for energy harvesting or targeting a RF transceiver for wireless communications (Figure 3).



A B C D E F

FIGURE 3 Radiation pattern at channel 7 at different feed points (A) centre top (B) centre bottom (C) left top (D) left bottom (E) right top (F) right bottom

This metaresonator antenna and antenna array design fulfils the objectives of this project, proving an innovative way to improve the deployment of wireless sensors in any built environment.

The Next Generation City-Scale Energy Benchmarking System

Pandarasamy Arjunan, Clayton Miller, and Kameshwar Poolla

Energy benchmarking is the practice of measuring and comparing the energy performance of a building with its peer groups, or against an established industry standard, with the goal of improving energy efficiency. It helps to identify opportunities for saving energy and also creates awareness among building stakeholders such as occupants, operational staff, architects, and engineers to make informed decisions to optimize and manage energy usage.

This is analogous to common labelling programs in the food industry. Recognizing its potential and importance, a growing number of governments around the world started to implement benchmarking (or energy disclosure) policies. Such policies include imposing regulations to meet minimum energy efficiency standards, certificate schemes for self-to-peer group comparisons, among others. As an example, the Building and Construction Authority (BCA) of Singapore publishes its energy benchmarking report every year.

Every building is distinct in terms of its physical attributes (gross floor area, age, orientation, number of floors/regions/rooms, built material and quality, etc.) and operational characteristics (primary function, schedule, occupancy, mechanical and electrical fixtures, etc.). These heterogeneous characteristics influence the total energy consumption of a building in a complex way. When benchmarking a building against its peer group, it is essential to normalize the energy consumption for all influencing factors, in order to enable a fair comparison. There are numerous normalization methods with varying complexity levels. One of the simplest and widely used methods is Energy Use Intensity (EUI) that normalizes the total energy consumption with respect to the gross floor area. On the other hand, simulation-based models can quantitatively account for many other factors that influence the energy performance of a building. Naive methods, such as EUI, are easy to compute and interpret but they fail to account for diverse influencing factors. Simulation models can provide detailed information about influencing factors, but they are very tedious in terms of required time, effort and expertise. This limits their applicability for city-scale benchmarking. What is required is an innovative blend of these two approaches to produce a scalable and interpretable benchmarking system that can account for most, if not all, of the energy influencing factors, to allow for a fair comparison of buildings.

In this project, we attempt to create a benchmarking method which is scalable at the city-scale and generalizable across all building use types.

We leverage advanced statistical and machine learning techniques to quantitatively measure the influence of each factor on the total energy consumption across buildings with different use-types. Based on their significance level, we also rank their relative importance of each factor in predicting the energy performance of building stock. Unlike other methods that focused on measuring the impact of each factor on total energy consumption individually (additive models), we study the interaction of building characteristics and measure their combined effects on energy performance. For example, what is the effect on the total energy consumption when using different air-conditioning systems in buildings of different ages? Our initial results show that models using interaction effects better capture the variability of the data, thus resulting in a better benchmarking of buildings.

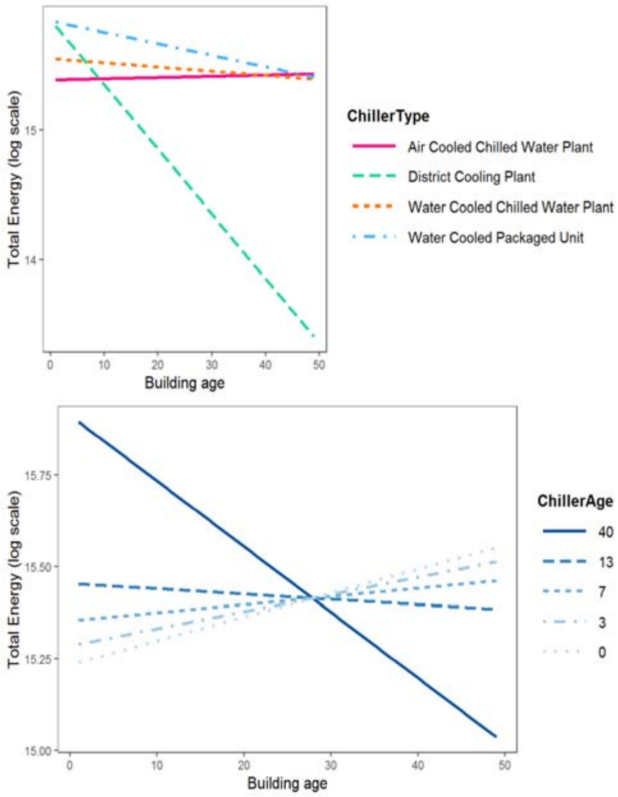


FIGURE 1 EUI profiles based on interaction of selected building factors

Cyber Physical Test-Bed

Costas Spanos and Edwin Goh

The SinBerBEST Cyber Physical Testbed is an invaluable crucible for proposed technological innovations, migrating technologies from concept to robust prototype and eventually to commercialization within a streamlined framework. It is used to verify the in-vivo performance, efficiency and effectiveness of technology innovations developed within our research.

The Testbed (Figure 1) offers:

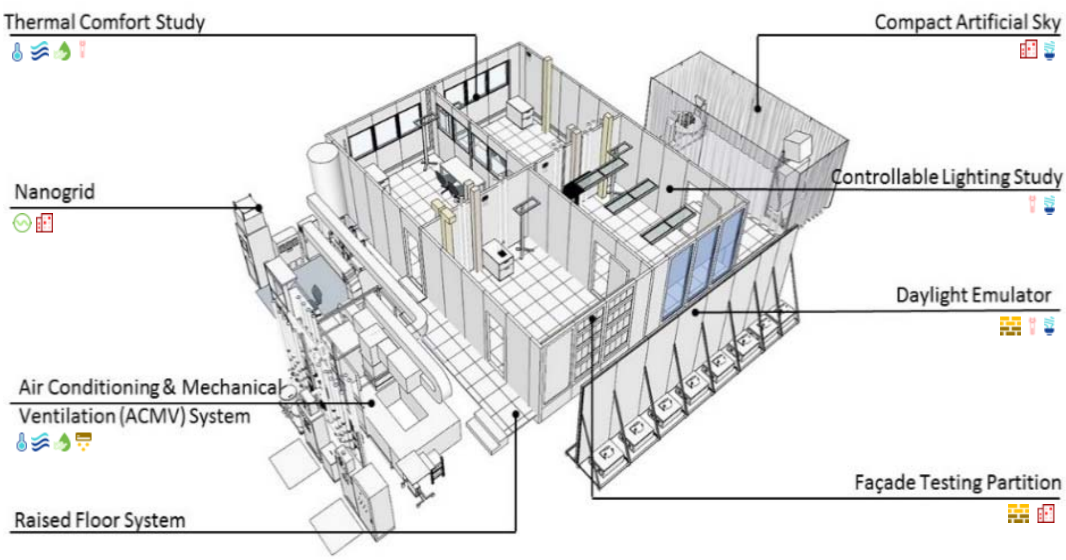
- The capability to execute real-time operation and control within the regulated indoor environments to support a wide range of research missions.
- Diversity in capabilities including a Daylight Emulator, an artificial sky, a fully controlled Air Conditioning and Mechanical Ventilation (ACMV) test-bed, a Nano-grid, and a Façade Management System
- Industry participation

Testbed Rooms I and II provide an environment for lighting and façade experiments to be conducted. The façade walls of Testbed Rooms I & II are configurable with the use of mounting frames. The Daylight Emulator is located next to it allowing complementary interaction studies between the Façade and the Daylight Emulator to be undertaken. The common wall between these two rooms is configurable giving the option of expanding the floor space between Testbed Rooms I and II to an area of 50 m².

Testbed Rooms III and IV are used for physical measurements and human subject experiments focusing on thermal comfort and Indoor Air Quality (IAQ). They offer opportunities to set desired thermal condition for each experimental need, such as air temperature, relative humidity or ventilation rates. This includes Alternating Current (AC) power simulator, Photovoltaics (PV) simulator, Battery Emulator (BE), Direct Current/Direct Current (DC/DC) converter, Grid-tied inverter, 3-phase programmable electronic load, and DC programmable electronic load. The equipment are either connected to DC distribution board or AC distribution board to set up a nanogrid system. AC and DC smart meters are installed in these boards to measure and display the values of voltage, current and power. Hence, the operation and response of individual equipment or the nanogrid can be monitored and controlled either locally or remotely.

FIGURE 2 Lighting and façade experiment in Testbed Room 1 using the Daylight Emulator

FIGURE 1 Overview plan of the SinBerBEST Cyber-Physical Test-Bed



The daylight emulator (DLE) can emulate diffused sunlight with respect to colour temperature and intensity. It can recreate lighting conditions related to different times of the day such as sunrise, blue sky and sunset. The DLE faces Testbed Rooms I and II and are therefore conducive for conducting lighting related experiments and visual comfort studies such as lighting control experiments (involving daylight harvesting), visual comfort and glare studies involving human trials and impact of sunlight on mood, comprehension and productivity.

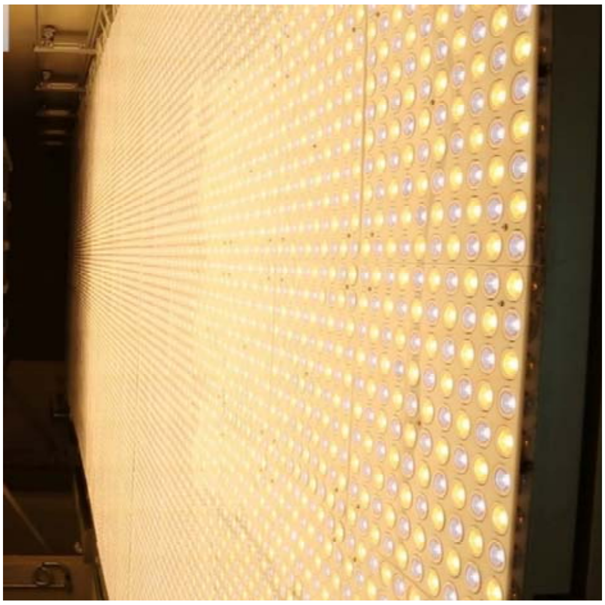


FIGURE 3 The daylight emulator has a colour temperature range of 24,000k-10,000k

The ACMV system comprises of: 1) *Control Algorithm* strategies to allow modern control research techniques such as model predictive control; 2) support *Indoor Air Quality and Thermal Comfort* research for physical and human subject studies to be conducted; and 3) allow ACMV Mechanical Subsystems research to compare and evaluate system performance.

The Testbed Building Management Services (TBMSvc) application is a customized Building Management System (BMS) that forms the central Command-Configure-Monitor platform for all devices and sub-systems in the SinBerBEST Testbed. The TBMSvc was custom built by SinBerBEST as an open-source web application due to the highly specialised needs of the Testbed.

The SinBerBEST PI System is the primary historian system for storing and managing experimental time-series data. At its core is the OSISoft PI System, which is a well-known data historian system in the Oil and Gas and Pharmaceutical industries. It is a windows-based system with industry standard big data processing and analytics capabilities.

The main advantage of using the OSISoft PI System is the ease of integration with low-level systems using its comprehensive library of interfaces. Thus, system integration of various types of sensors, actuators and sub-systems that are adopted by SinBerBEST (ACMV, Lighting, etc.), which would traditionally have required a lot of software development effort, is made easy with the use of PI OSISoft platform.

Compact Artificial Sky (CAS) is a novel instrument that enables researchers to evaluate the daylight performance of a building model. Unlike the full sky dome, which uses a moving light source and a stationary building model, the CAS follows the opposite approach in which the building model is rotated using a turntable while the light source is fixed. Although the CAS has a smaller footprint than a full sky dome instrument, it delivers accurate results.

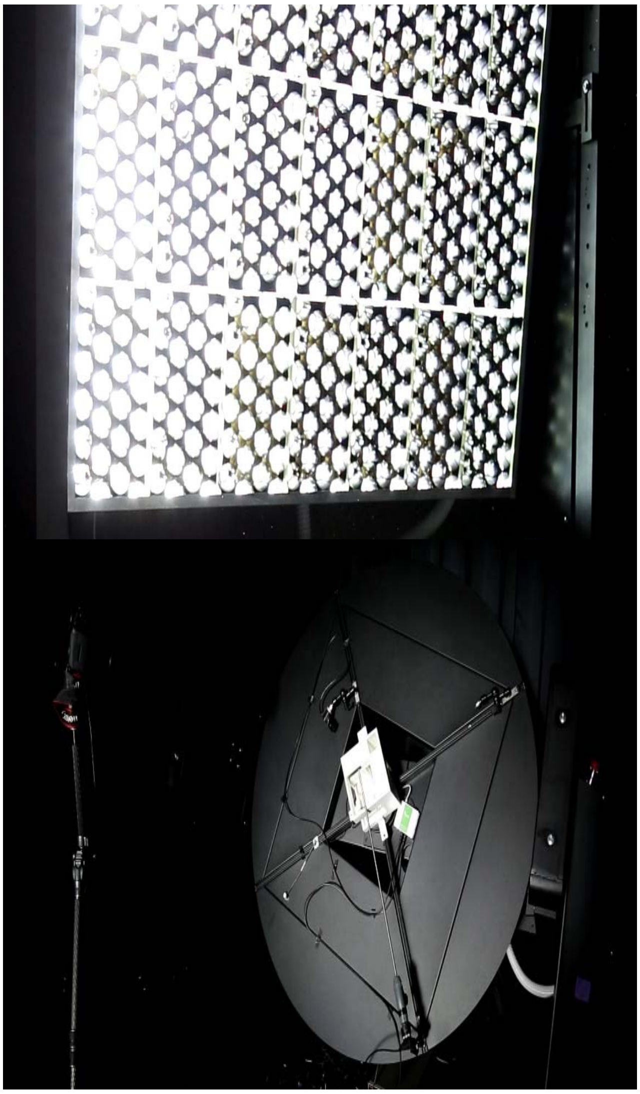


FIGURE 4 Compact Artificial Sky (CAS) is a novel instrument that enables researchers to evaluate the daylight performance of a building model.

2018 Building and Environment Best Paper Awards.

Research collaboration between SinBerBEST and UC Berkeley's Center for the Built Environment (CBE) resulted in three Building and Environment (BAE) Best Paper Awards in 2018. The BAE is a global publication that shares novel building science and human interaction with the building environment study findings. It established these awards in 2007 to recognize authors for their papers' originality, industry contributions, presentation quality, and science validity. BAE selects three Best Paper Awards every year. This is a significant achievement as there were over 3000 paper submissions in 2018, and SinBerBEST and UC Berkeley's CBE research teams won all three awards.

Building and Environment recognized the following papers:

Automated Mobile Sensing: Towards High-Granularity Agile Indoor Environmental Quality (IEQ) Monitoring
The cost of installing and maintaining numerous sensors throughout a building makes it challenging to accurately monitor buildings. Ming Jin, an UC Berkeley EECS PhD graduate and a former SinBerBEST researcher, along with SinBerBEST 2 and CBE researchers, created an autonomous robot, or the IEQ Bot, that can navigate and map the building interior, measure indoor environmental quality using a wireless sensing platform, and precisely assess buildings.

Authors listed in order of contribution: Jin M, Liu S, Schiavon S, Spanos C.

Development of the ASHRAE Global Thermal Comfort Database II
In summer of 2018, CBE completed compiling the biggest database in thermal comfort field study data, and released new online tools for considering thermal comfort issues, and for fostering climate-reactive and inviting low energy (as well as Zero Net Energy) building designs.

Authors listed in order of contribution: Földváry V, Cheung T, Zhang H, de Dear R, Parkinson T, Arens E, Chun C, Schiavon S, Luo M, Brager G, Li P, Kaam S et al.

Personal Comfort Models: Predicting Individuals' Thermal Preference Using Occupant Heating and Cooling Behavior and Machine Learning
In this paper, the authors detailed an innovative approach to thermal comfort modeling that predicts individuals' thermal comfort more accurately than using the average of a standard population. These insights were based on CBE's "Changing the Rules" field study findings.

Authors listed in order of contribution: Kim J, Zhou Y, Schiavon S, Raftery P, Brager G.

IEEE Conference on Decision and Control Workshop on Smart Buildings

On December 16 2018, at the 57th IEEE Conference on Decision and Control in Miami Beach, Florida, USA, Professors Rong Su, Costas Spanos and Xie Lihua spoke at the workshop on Smart Buildings: A Status Quo Check. Co-organised by Prof Rong Su, the workshop was held to report and showcase several recent technical progresses related to smart buildings at both individual and program levels, and some visionary discussions on the roles of IoT and formal design methods. It was also held to identify challenges ahead which, although hindering the current research efforts, are critical for developing smart buildings, in order to arouse more interests and efforts at a broader societal level to ensure R&D sustainability. Prof Xie spoke on the indoor positioning systems: some recent development and challenges;

Prof Su expanded on the topic of IoT-based HVAC scheduling for smart buildings; and Prof Spanos discussed on designing a living laboratory for building energy efficiency in the Tropics.

More details of the workshop can be found here: https://intelligentsystems.eee.ntu.edu.sg/cpisrg/CDC18.html

Professors Xie Lihua, Costas Spanos and Rong Su who presented at the workshop.

New Staff Member

Marcus Maier joined SinBerBEST 2's Theme C team in November 2018. His research will address the structural metamaterial development for building systems. Metamaterials are systematically structured materials that can be tailored to specific applications. When used in building envelopes, these novelly-designed metamaterials have three properties that meet an energy-efficient and sustainable façade system's requirements. One, they are light-weight materials with improved thermo-mechanical properties. By using 3D-printed cellular metamaterials in the building envelope created by combining additive manufacturing methods (such as 3D printing of concrete with extruded polymer reinforcement elements,) thermo-mechanical performance is enhanced, and material usage and waste are reduced. Lastly, energy consumption and CO2 emissions are further decreased in the construction industry. Two, metamaterials have materials and elements that reduce solar heat gain. Three, as they can cool and dehumidify incoming air, a so-called "breathing façade" structure is being developed. It is capable of using multi-modal cooling and natural ventilation to improve human comfort.

Marcus brings to SinBerBEST 2 his research expertise gained from Austria and USA. He received his PhD from the University of Innsbruck in Austria, and has been a Botstiber Fellow at the University of New Orleans/USA and a Marshall Plan Research Fellow at the University of California, Berkeley/USA. During that time, Marcus contributed to various research projects on: 1) fire testing, damage assessment and thermomechanical analysis of structural concrete, and elastomer-based bridge bearings, 2) experimental characterization of the impact behavior and structural health monitoring of concrete and cement-based materials, and 3) pore space manipulation and analysis of high performance ceramics, as well as fatigue and mechanical characterization of fiber-reinforced polymers.

President Janet Napolitano's Visit to BEARS HQ in Singapore

The University of California President Janet Napolitano visited BEARS on Tuesday 18th February 2019. Her visit to BEARS was part of a series of government and university meetings across Asia to expand University of California's research and education partnerships.

President Napolitano is the 20th President of the University of California, and the first woman to serve in this role.

She leads a university system of 10 campuses, five medical centers, three affiliated national laboratories, and a state-wide agriculture and natural resources program. The UC system has more than 273,000 students, 223,000 faculty and staff, an operating budget of $36.5 billion, and two million living alumni.

President Napolitano has launched an initiative to accelerate the translation of UC research into new businesses and inventions that benefit the public good.

The visit began with an overview presentation of both the SinBerRISE and SinBerBEST programs. Project demonstrations and a test bed tour were presented by Mr Edwin Goh, post doctoral scholars Dr Krishnanand, Dr Karunagaran, Dr Mishra, Dr Huynh, Mr Christopher Soyza and research engineer Komang Narendra. Dr Krishnanand presented in energy grid and smart sockets. Dr Karunagaran explained our state-of-the art modular air-conditioning and mechanical ventilation systems. Edwin Goh presented our daylight emulator and translucent concrete panel and explained its role as

a multi-functional façade. Dr Mishra and Huynh explained the use of elevated temperature setpoint and increased air movement technology to significantly reduce energy consumption in tropical buildings, while Mr Komang and Mr Soyza spoke about the use of the compact artificial sky and building in a briefcase project.

President Napolitano delegation included UC Santa Barbara Chancellor Professor Henry T. Yang, Provost and Executive Vice President for Academic Affairs Michael Brown, Associate Vice Provost and Executive Director of the Education Abroad Program Vivian-Lee Nyitray, and Strategic Engagement Manager Corey S. Feinstein.

The BEARS team hosted the delegation at CREATE. The BEARS Investigators on hand for the welcoming program were: Prof. Kameshwar Poolla (UCB), Prof. Sanjib Panda (NUS), Prof. Su Rong (NTU), and Dr. Zuraimi Sultan, SinBerBEST's Program Director.

President Napolitano praised the research efforts of SinBerBEST as leading to cutting edge technology for future. She foresees great potential in applying SinBerBEST technologies and management of similar synergistic research for UC campuses.

SinBerBEST aims to deliver energy efficient building technologies for the tropical built environment, while optimising human comfort, safety, security, and productivity within the building. This interdisciplinary research project is organised into five themes (A – E) :

A - Human-Building Nexus
B - Smart Technologies and Resilient Buildings
C -Agile Design for Energy Efficiency and Human Comfort
D - Data Analytics
E - Test Beds and Deployments

If you are interested to learn more about our program, participate in our research or use our test-bed facilities, please contact Dr. Zuraimi Sultan at zuraimi.sultan@bears-berkeley.sg

or

visit us at www.sinberbest.berkeley.edu

SinBerBEST

The SinBerBEST program, funded by the National Research Foundation (NRF) of Singapore, is a research program within the Berkeley Education Alliance for Research in Singapore (BEARS). SinBerBEST is an interdisciplinary group of researchers from University of California, Berkeley (UCB), Nanyang Technological University (NTU) and National University of Singapore (NUS) who come together to make an impact with broadly applicable research leading to the innovation of energy efficient and sustainable technologies for buildings located in the tropics, as well as for economic development. SinBerBEST's mission is to advance technologies for designing, modeling and operating buildings for maximum efficiency and sustainability in tropical climates. This newsletter, published quarterly, is to showcase the excellence of SinBerBEST faculty, post doctoral fellows and students.

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