Machine learning (ML) is beginning to transform many facets of the way we live, work and play. The building industry and the research community around it are quickly working on ways to understand how ML techniques best serve objectives such as energy efficiency and occupant health, comfort and satisfaction. SinBerBEST 2 Theme D is focused specifically on Data Analytics and ML for buildings and ways to optimize and improve the use of data-driven techniques.

One key question for the application of ML is what is the best configuration of models, parameters, and steps that produce the most accurate results. Accuracy is important in the context of how useful a model is for a given application. This aspect has traditionally been a challenge for researchers in the built environment as much of the literature in this field focuses on individual case studies. Creating an accurate model with a small data set from a single building is actually not useful in understanding how behaviour can be predicted at a larger scale. The only way to determine which model is the most accurate is to create several scenarios and test them against each other. A good researcher might be able to do this for a handful of models, but a new technique of ML competitions allows the models from thousands of experts to be compared to find the best solution. These ML competitions are common in numerous industries from real estate, medicine, marketing, and climate change, but they haven’t been recently applied to the context of buildings.

GEPIII is a resurrection of previous ML competitions held by ASHRAE in the past. The Great Energy Predictor I and II competitions were held in the mid-1990s led by Jeff Haberl and Jan Kreider at the University of Colorado and Texas A&M University. These competitions set the stage for data-driven building energy prediction innovation in the early days of artificial intelligence research for buildings. Many new techniques, tools, and data sources have emerged in the more than twenty years since those early competitions; not the least has been the widespread use of the internet and crowdsourcing platforms like Kaggle. ASHRAE TC 4.7 discussions in 2018 were the catalyst for the competition’s resurrection utilizing these innovations and focusing on a far more extensive data set. Jeff Haberl was the team’s link to the previous competitions, and he was a strong motivator in renewing the effort in a new form.
The objective for the participants in the competition was to uncover the machine learning workflow that resulted in the lowest accuracy-based error. This error calculation was based on how well a contestant’s prediction model performed in the context of predicting long-term hourly energy measurements from buildings. These data included 2,380 energy meters representing electricity, heating and chilled water, and steam energy consumption from 1,448 buildings in 16 different data donor locations. The primary technical goal was to discover which model types, machine learning steps, and workflows performed the best on this specific application. At the end of the competition, the teams with the most accurate predictions would win the prize money in return for sharing their code and explanations of their solutions. These technical objectives are interesting for anyone seeking the most innovative ways of performing machine learning on building energy. Figure 2 shows the process for the participants to compete in the contest.

Beyond just technical aspects, the planning team had the key objective for the competition to push the data science and building science communities closer to each other through an exchange of concepts, terminologies, and techniques. Kaggle’s 5 million users and ASHRAE’s 50,000 members had a limited overlap before the competition. Machine learning experts knew little about buildings, and building energy analysts only used the most basic machine learning techniques. The goal was for this competition to be a catalyst for exchange that would continue post-competition.

The most critical technical discoveries from the competition were based on finding which types of models and configurations performed best for this application and the steps in the machine learning process that yielded the best results at this scale. Decision tree ensemble models such as Gradient Boosting Trees were the most popular and effective model type for time-series hourly energy regression in this context. These model types can be implemented using numerous open-source Python and R packages such as XGBoost and LightGBM. Another significant finding was that all of the machine learning workflow steps had an impact on model accuracy and some of those activities required domain knowledge to undertake. For example, one member of the top winning team had some background in metering and understood the best way to preprocess the training data to remove anomalous behavior that would reduce their solution’s effectiveness. Figure 3 illustrates an overview of the structure of the solution from the first place team. It was also found that the best solutions were not just a single trained model but large ensembles of models whose predictions were post-processed to create the right balance in the bias-variance tradeoff needed to win. These technical insights form the foundation for researchers when approaching building energy prediction for large groups of buildings.

The competition results have been shared in several open-source repositories that give future analysts and researchers a starting point for leveraging the discoveries. The primary repository contains the code and detailed documentation of the top five winning solutions and includes several links to YouTube playlists containing detailed explanation videos from the winning teams. Another repository contains data from the competition itself in terms of the contestants, discussion board topics, and other information about the planning of the competition. Finally, the competition data was open-sourced in a repository and open-access publication, and it includes additional data sets and documentation not found in the competition (Miller et al, 2020b).
From a practical perspective, the biggest takeaway for engineering and energy professionals is that it’s essential to learn new tools such as coding as the amount of data grows in our industry. This competition provides hundreds of analysis examples in the form of notebooks that were created by the contestants and can be cloned and learned from by professionals who want to pick up Python or R programming languages. A large percentage of these notebooks and the discussion that accompanies them are targeting data science beginners. We hope that coding and data science skills will become commonplace as part of a digital hybrid skill set of any building performance-related professional due to the competition’s content.

Beyond the repositories and online sources of information listed previously, several ASHRAE Seminar videos can be watched to learn about the competition’s planning and results. The following seminars and presentations can be found in the ASHRAE digital archive and viewed for more information:


Acknowledgements
SBB2 Theme D would like to thank the Kaggle staff (Sohier Dane, Addison Howard), and the ASHRAE GEPIII technical/planning committees (Chris Balbach, Krishnan Gowri, Anjukan Kathirgamanathan, Chun Fu, Bianca Pichetti, Jonathan Roth, June Young Park, Zoltan Nagy, Anthony Fontanini, Jeff Haberl) as the competition would not have been possible without them.

References
Occupant satisfaction surveys are widely used in research to explore the effect of the built environment on people. If defined and used properly, surveys can provide a wealth of information to help building owners, designers, researchers, and occupants identify building features and characteristics that function as intended and areas that need improvement. However, deploying surveys in real office settings poses several challenges because researchers do not have precise control over the indoor environment experienced by building occupants, occupants can be difficult to recruit and retain, and data collection methods can be cumbersome.

We developed and tested a new method which we call the Targeted Occupant Survey (TOS) platform, shown schematically in Figure 1. The goal of the new method is to target survey requests based on researchers’ objectives to minimize disruptions to the building occupants while maximizing the amount of useful data collected. The platform allows us to explicitly define the indoor environment measurements at which we push out the surveys to occupants while maintaining researcher defined distribution constraints. We designed the TOS platform to be sensor-agnostic and to interface with any survey service as long as they support code execution in the Python environment.

Targeted occupant survey (TOS) platform overview. The top schematic shows a high-level overview of how TOS projects are set up while the bottom schematic shows the TOS program flow.

**FIGURE 1** Targeted occupant survey (TOS) platform overview. The top schematic shows a high-level overview of how TOS projects are set up while the bottom schematic shows the TOS program flow.
Buildings account for more than one-third of the electricity consumed in Singapore in 2019. This indicates their high potential in managing the nation’s power consumption by regulating the operational demand. Building clusters are considered as demand centres for highly urbanized Singapore and for that matter any other smart city. But they are distributed and heterogeneous demand centres that often operate independently, and this necessitates their scalability and decentralized coordination to act towards the common goal of system-wide demand management. Additionally, under this new paradigm of “demand following generation” or “demand assisted power system operation”, the buildings must be able to transact energy-related valuables in suitable markets. U.S. Department of Energy in 2020 has identified this research challenge as Connected Communities (CCs) which are collections of buildings and distributed energy resources (DERs) that incorporate integrated energy management strategies at the multi-building scale, to unlock greater value and economies of scale, versus the building-by-building approach. It requires demand response (DR) schemes which narrow down the rules of transaction and Singapore already has the first version of such a scheme implemented targeting large reducible loads. But this also means that buildings must have corresponding cyber-physical infrastructure to meaningfully participate in the market as an individual agent and also to execute the market decisions made. For these purposes as stated above, in our recent publication, we propose a generalized hierarchical transactive energy (TE) based multi-agent framework that includes

FIGURE 2 Visualization of point dispersion in actual datasets for our pilot study, Liu et al. (2019), Kim et al. (2019), and Cheung et al. (2017). Ideal datasets contain the same number of points as their respective actual dataset.

Transactive Energy Market Framework for Decentralized Demand Management for Buildings

Rohit Chandra, Krishnanand Kaippilly
Radhakrishnan, Sanjib Kumar Panda

We performed a pilot study to test the TOS platform at the David Brower Center in Berkeley, California, a radiantly conditioned building. We then compared our TOS dataset with three other datasets that used typical administering methods such as scheduled surveys and surveys completed based on occupants’ discretion. Our results show that our TOS collected dataset has a higher approximation to characteristics of an ideal dataset; 41% compared to 23%, 19%, and 12% of other datasets in previous field studies. Figure 2 shows the actual (blue) and ideal (gray) data point distribution for each dataset we compared. The higher percentages indicate less clustering of data points which means a more diverse set of environmental conditions where occupants responded to satisfaction surveys.

Compared to other survey methods, the TOS platform allows building stakeholders to more quickly and effectively collect data necessary to answer research questions and evaluate indoor environmental quality while limiting unnecessary disturbances for building occupants.

Reference

SMART & ENERGY TECHNOLOGIES
Energy Management Demand Agents (EMDAs) at the building level to actively participate on day-ahead Walrasian market and to coordinate load operations within buildings. EMDA is represented in Fig. 1 and a schematic of the proposal is shown in Fig. 2. Through our study, we demonstrate the possibility of avoiding power dispatch from expensive generation units by reducing peak demand and providing demand response inherently.

Through our study, we demonstrate the possibility of avoiding power dispatch from expensive generation units by reducing peak demand and providing demand response inherently.

In the proposed TE framework, the followings are considered:

A) TE-Based Agents for Generation Units: To represent both base-load and peak-load generation units in the electricity market, agents that respond to the electricity price vector for the upcoming intervals with their electricity generation bid curve are used. Each generator agent uses dynamic programming to make decisions of unit commitment and optimal power generation based on a quadratic operation cost model along with startup and shutdown costs.

B) TE-Based Agents for Buildings: The EMDAs represent buildings in day-ahead electricity market participation and act as decentralized scheduler of building loads that are grouped as discussed below. The decisions at the building level are customizable through economy preference factors, as selected by the energy consumer for each load group.

i) Deferrable appliances: Use of appliances such as pumps, mixers, water heaters and machines with known power consumption patterns can be deferred to avoid high electricity periods and reduce electricity cost, while also considering the associated discomfort cost of waiting.

ii) Power controlled appliances (like air conditioning): Optimal temperature set-points that ensure both economy and thermal comfort of occupants are decided, by maintaining a tolerance band around the temperature set-point.

iii) Energy Storage Devices (ESDs): Optimal charging and discharging decisions, which utilize price arbitration in a Time-of-Use (ToU) pricing scheme, are made to maximize revenue and minimize ESD aging costs.

iv) Uncontrolled net loads: Critical appliances and photovoltaic generation combine to form the uncontrolled group of net loads.

C) TE-Based Market Agent: A transactive market agent that follows Walrasian Auction and tâtonnement mechanism considering multiple buyers and sellers is used to clear the market. The price vector for a rolling horizon of next 24 hours is shaped by a clearing process that checks mismatch in aggregated supply and demand vectors, for iterative and decentralized adjustments to individual supply and demand vectors by corresponding agents. This process is repeated every hour.

A cyber setup was formed as shown in Fig. 3 to test our proposal. In this communication network, Texas Instruments Tiva-C micro-controllers were used to contain the generator agents, Raspberry Pi 4 single board computers were used to contain multi-threaded EMDAs, and a personal computer was used to simulate the market agent and to perform visualizations.

Three cases were considered for testing – 1) baseline case of maximum comfort and flat electricity pricing, 2) transactive control case of randomly generated economy preference factors, and 3) demand response case considering outage of a generator. A comparison of the results from testing the cases is given in Table I. The results clearly illustrate that 20%-30% reduction in peak power could be achieved by the building cluster through decentralized demand management by the agents used in the proposed TE framework.

Reference

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![FIGURE 1](image1) Representation of Energy Management Demand Agent (EMDA)

![FIGURE 2](image2) Hierarchical TE market proposal

![FIGURE 3](image3) Hierarchical TE market proposal

---

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline Case</th>
<th>TE Control Case</th>
<th>Unit Outage Case</th>
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</thead>
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<tr>
<td>Bills ($/day)</td>
<td>38,935</td>
<td>33,224 (-14.64%)</td>
<td>34,820 (-10.55%)</td>
</tr>
<tr>
<td>Energy (MWh)</td>
<td>1,254.0</td>
<td>1,120.3 (-10.66%)</td>
<td>1,115.9 (-11.01%)</td>
</tr>
<tr>
<td>Peak (MW)</td>
<td>104.35</td>
<td>79.53 (-23.78%)</td>
<td>73.65 (-29.42%)</td>
</tr>
</tbody>
</table>

TABLE 1 Comparison of the cases tested on the cyber setup that implements the proposal

sinberbest.berkeley.edu
A dimensionality reduction method to select the most representative daylight illuminance distributions

We used a widely utilised method of dimension reduction, known as principal components analysis. This reduced the daylight distribution patterns from the temporal conditions into a smaller number of principal components. Each principal component was used to derive a representative daylight distribution pattern, whereby the identified condition was found to be similar to many other cases that were analysed. For the “Shoebox” model, our approach reduced thousands of temporal conditions from an annual daylight simulation in Singapore into three representative distributions. When combined, these explained up to 99 % of the information that was contained in the original simulation data used to perform the analysis.

When applied to another climate and to the complex model, our approach reduced the temporal conditions into a far fewer number of representative daylight patterns. While these identified cases from the analyses can be used for further evaluation by the researcher or designer, our approach significantly enhances the interpretability of – what would otherwise be considered as – an overwhelming amount of daylight simulation data.

Climate-based annual daylighting simulations model the dynamic distribution patterns of natural light inside of buildings. These are communicated in research and practice as aggregate performance results. In practice, daylight distribution patterns on the horizontal plane – that represent workstation surfaces – are evaluated at standardised time periods across the solstices and equinoxes under specific sky conditions. The alternative being an arduous process of evaluating hundreds, if not thousands of annual time conditions corresponding to the occupied hours of the given building design. This approach creates an equal amount of daylight illuminance data and visualisations that the designer needs to carefully analyse.

We propose another method, whereby one single analysis can evaluate all possible daylight distribution patterns produced from an annual simulation. To demonstrate our approach, we utilised two different models and simulated horizontal daylight distribution patterns using the software DIVA. Annual simulations were performed in two different locations (Oakland, California and Singapore) with an office-based occupancy schedule. When considering the daylight distribution patterns that occur at every hourly interval, over three thousand different temporal conditions were created and needed to be evaluated.

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Infrared thermography for city energy analysis

Miguel Martin, Kameshwar Poolla, Clayton Miller

Infrared thermography has been used at multiple scales of the built-environment for different purposes (Fig 1). At the mesoscale, the scale between 10 and 200 kilometers, infrared thermography has been considered in many studies to assess urban heat islands, that is temperature differences between urban and rural areas (Ngie et al., 2014). Urban heat islands are assessed using thermal images collected from satellites. Thermal images obtained from an observatory can be used to analyze the building energy performance at the local-scale, the scale between 100 meters and 50 kilometers (Dobler et al., 2019; Sham et al., 2012). However, local-scale studies of the building energy performance are less frequent than microscale studies (Kirimtat & Krejcar, 2018; Kylili et al., 2014; Lucchi, 2018; Nardi et al., 2018; Rakha & Gorodetsky, 2018). For this reason, it was decided to focus on infrared thermography at the local-scale.

To study the building energy performance at the local-scale, an observatory will be installed at different positions in the university campus of the National University of Singapore (NUS). The observatory will essentially consist of an infrared camera to collect thermal images at several instants. The objective is to establish a correlation between the surface temperature measured by the camera and the energy consumption recorded by a building management system. The correlation will be established based on image and signal processing techniques.
Fig 1 shows the observatory it is intended to install at the rooftop level in the NUS campus. The infrared camera will be fixed on pan/tilt unit that can automatically rotate with a certain angle. Together with the pan/tilt unit, the infrared camera will be installed on a 2-meter-high truss tower. The truss tower will be stabilized with concrete units placed on the bottom plate. To collect and store thermal images, the infrared camera will need to be connected to a laptop. The laptop will be enclosed in box containing a backup battery and a lightning surge arrester. The box will be rated IP65 to protect the laptop, the backup battery, and the lightning surge arrester against heavy rain. In addition to heavy rain, the observatory will be protected against lightning with an air terminal installed at the top and an aluminium tape connected to the existing lightning system. All electrical instruments, that is the infrared camera, the pan/tilt unit, and the laptop, will be powered up by the electrical source of the building. To interact with the laptop remotely, it will be connected to Internet by 4G.

The observatory will subsequently operate at the rooftop of Kent Vale Blk A and CREATE for three months at least.

From these positions, it will be possible to observe various buildings in NUS campus, whose energy consumption is monitored with a building management system. Buildings will be laboratories and offices as it will not be possible to observe residences due to privacy issues. As shown in Fig 3, it will be possible to capture thermal images of Engineering and CREATE buildings from the rooftop of Kent Vale Blk A. As thermal images will be continuously collected over three months, it will be possible to analyze the energy performance of these buildings over the day and at night. At the rooftop of the CREATE building, on the other hand, a different side of Engineer buildings will be observed. In addition to Engineering buildings, it is planned to study the energy performance at the School of Medicine, where high-rise and highly glazed buildings were constructed.

The surface temperature of buildings will be measured with a FLIR A300 infrared camera. The infrared camera operates within a spectral band of 7.5 – 13 μm. It has a field of view of 25 x 18.8 degrees, and can produce thermal images with a resolution of 320 x 280 pixels. The accuracy with which the surface temperature can be measured is ± 2 °C.
Electrical plug-load management is a significant aspect in managing building energy due to the high plug-load consumptions in modern buildings. To measure desk plug-load consumption in a practical scenario for office buildings, a living lab at BCA Academy’s at the first floor of BLK-A building has been instrumented with Plugwise smart plugs. The deployment spans 53 desks across three zones with each desk having six Plugwise devices totalling 318 Plugwises, with >96.2% of them belonging to zone-1 or zone-2. Each Plugwise measures active energy, power and relay status for the respective plug-load, communicates to an IEEE 802.15.4 ZigBee local base station, which are then read by a Raspberry Pi device and are sent to OSIsoft PI system database for later retrieval of their time-series. The aggregate consumptions per phase are measured too for zone-1 and zone-2, using sub-meters from National Instruments. Owing to the electronics used in the Plugwises, they consume a large amount of standby power that leads to their high contribution to monthly building energy consumption. This could be mitigated by switching the operating configuration of the Plugwise from a flat system to a hierarchical system where a master Plugwise switches off supply to the terminal Plugwise devices and their loads during predetermined times such as nights and weekends. A representation of this change is shown in Fig. 1.

To estimate the energy savings possible from the proposed hierarchical system, a what-if analysis was performed using real metered data. The counterfactual scenario posed applies a schedule on the master Plugwise to turn off supply to the extension board, terminal Plugwise hardware units and the desk plug-loads during Saturdays, Sundays, and every night (11PM-7AM). Real data from three recent months are used in calculating the actual energy consumption of desk plug-loads and simulating the counterfactual scenario of hierarchical configuration. The outcome of the analytics for January 2021 is shown in Fig. 2 and 3.

To quantify the energy usage, Effective Energy Use Intensity (EEUI) is defined as (days in a year x kWh consumed in a month)/(days in a month x applicable floor area in m²). The findings on EEUI reductions possible are shown in Fig. 4. They represent an average savings of 33.56%, which is equivalent to a reduction of 123.52 kWh/month in energy and corresponds to an EEUI reduction of 2.21 kWh/m² per year. Even though the master Plugwise can add a monthly consumption up to 42 kWh, its intelligent scheduling can reduce the overall consumption of the desk plug-load management system and thus benefit the building.

**FIGURE 1** The non-hierarchical and hierarchical arrangements considered for the Plugwise devices in the living lab.
**FIGURE 2** Hourly energy consumptions of desk plug-loads and losses due to the controlled energy delivery system (i.e. terminal Plugwise units and electrical extensions) using Jan2021 data

**FIGURE 3** Hourly energy consumptions of desk plug-loads and losses due to the controlled energy delivery system (i.e. master Plugwise unit, terminal Plugwise units and electrical extensions) from counterfactual estimation based on Jan2021 data

**FIGURE 4** Changes in EEUI possible for each month in the desk plug-load consumption through the application of a hierarchical configuration and corresponding schedule
**Dr. Xu Xinping Interview**

For this issue, we talked with Dr. Xu Xinping who is a research fellow working under Prof. Xie Lihua at Nanyang Technological University. He has a deep wealth of machine learning expertise and is working on a Theme B project at SinBerBEST.

*Can you briefly describe your education background?*

I obtained my bachelor’s degree from Nanjing University, China in 2015. During my undergraduate, I majored in statistics from the Department of Mathematics. Afterwards, I decided to study artificial intelligence and economics. In the fall of 2015, I obtained the Singapore University of Technology and Design PhD President’s Graduate Fellowship and started my PhD career in SUTD. I was in the Engineering Systems and Design Pillar and under the guidance of Prof. Lingjie Duan. I was interested in the interdisciplinary research field combining computer networks and game theory. I focused on unmanned aerial vehicle wireless network optimization problems, public facility localization problems and distributed network control problems on machine learning. In the first half year of 2019, I was fortunate to be a visiting student at the City University of Hong Kong and acquired achievements on studying activity scheduling games. Between October 2019 to January 2020, I was a visiting scholar at the Purdue University, IN, USA, and worked on speeding up matrix-matrix multiplications in machine learning.

*How did you get into this field?*

My past research focused on game theory, but I wish to study more applicable and realistic field in our life. Through a colleague, I came to hear about research on Multimodal Occupancy Estimation and Prediction Program in NTU led by Prof. Lihua Xie. Although I did not major in environmental quality and building energy efficiency in my PhD, my background on statistics, data science and machine learning is very relevant in this field. I collected the data on office WiFi-detected mobile devices and CO2 concentration, and then used random forest, time inhomogeneous Markov chain and support vector machine to predict building occupancy.

*What drew you to the SinBerBEST program?*

As I know, SinBerBEST is an interdisciplinary group of researchers from UC Berkeley, NTU, and NUS, who come together to make an impact with broadly applicable research leading to the innovation of energy efficient and sustainable technologies for buildings and economic development. I feel lucky to have such big opportunity to cooperate with top scientists from various fields in this one of the most valuable research program in the world. From the perspective of personal research support, SinBerBEST provides sufficient funding for my project, the best experimental facilities and equipment and conducive office environment at CREATE Tower -- which satisfy all needs for researchers. Prof. Lihua Xie’s group is at the leading-edge of research direction on sensing technology under challenging circumstances such as WiFi sensing under spatial dynamics and occupant estimation under machine learning models. Through the program, I can learn considerable new knowledge and enhance my practical working ability.

*How does your work at SinBerBEST build on your past research?*

During my PhD, I mainly focused on algorithmic game theory. In this field, I studied how should the government deploy some public facilities on a street to serve the residents nearby by gathering resident location information and make sure that each resident truthfully provides his location information. I perfectly designed various mechanisms to fit in all scenarios. Now, I need to develop an accurate and
reliable occupancy estimation and prediction methods in intelligent buildings and environments based on multi-sensor and vision forecasting. Based on my past research on pure theory, I am more eager to extend to study realistic applications by using machine learning models. My PhD strong experiences in processing sensor data, visual data and positioning data, and familiarity with machine learning and programming certainly help me to do my research in this program.

How can your research benefit people working in the building and other industries?
In my project, we aim to develop an accurate and reliable occupancy estimation and prediction method. With accurate and reliable occupancy information, we can analyse activity pattern of occupants, improve understanding of users’ behaviors and usage of shared space, and have better control of HVAC and lighting for building energy efficiency.

What are your longer term goals?
My main long-term goal is to keep working hard in this field and publish high-quality research papers using experimental data. Finally, I hope my experience in SinBerBEST will help me in applying for a faculty position in a university.

We wish Dr Xu all the best.

Beyond Academia Talk
On the 25th May, Professor Joel Ager, a Staff Scientist from the Materials Sciences Division of Lawrence Berkeley National Laboratory (LBNL) gave a career talk to CREATE postdoctoral fellows, PhD and Masters students. Prof Ager shared his experience and career details working in the national laboratory, and provide background info on LBNL organization, its mandate and potential career paths which may be different from academia. The talk also provided opportunities for attending postdocs and students to ask questions to the speaker.

Arrivals and Departures
We welcome....
- Alan Wan, System Administrator and Developer
- Dr Wu Zhibin, Postdoctoral Scholar
- Dr Xu Xinping, Research Fellow
- Dr Miguel Martin, Senior Postdoctoral Scholar
- Dr Nishant Kumar, Research Fellow
- Dr Janaki Santosh Raman, Research Fellow

We bid farewell to....
- Dr Jia Hongyuan, Postdoctoral Scholar
- Ivanna Hendri, Design Engineer
- Dr Asit Mishra, Postdoctoral Scholar
- Sneha Ranjit, Software Engineer
- Sivasithamparam Karvannan, System Administrator
- Dr Yang Jianfei, Research Engineer
- Chris Hsu, Applications Programmer

SinBerBEST Principal Investigators interviewed in Singapore newspaper Lian He Zao Bao
Professors Schiavon, Tham and Sekhar were interviewed in the Lian He Zao Bao, the largest Singaporean Chinese-language newspaper with a daily circulation of about 200,000. The article discusses the Singapore government updated guidelines on improving building ventilation to strengthen the resilience against COVID-19 pandemic. Prof Tham and Sekhar noted that future building design should have both pandemic and non-pandemic modes of operation. The latter will focus on sustainable development, low-carbon or carbon-neutral operations and energy efficiency while the former will focus on protecting and slowing down the spread of the virus, combined with pre-conceived administrative control, to provide proper protection. Prof Schiavon shared the findings on energy impacts of higher ventilation under pandemic mode of buildings and also it may cause thermal comfort issues. However, it was agreed that building stronger resilience is imperative, because the cost of not taking adequate measures is higher and incommensurate.
Lian He Zao Bao article on the government’s updating of the guideline on improving building ventilation to strengthen the resilience against COVID-19 pandemic

政府更新建筑物通风守则 加强防疫韧性

文章来源：sinberbest.berkeley.edu

2021年06月06日 星期日

研究：通风系统力度每添一成 大楼耗电增1%

政府更新建筑物通风守则 加强防疫韧性

2021年06月06日 星期日

拟增加措施

建屋局将为其商场和办公楼加强通风

联合早报

2021年06月06日 星期日

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