SinBerBEST

Machine Learning Crowdsourcing

Spring 2021
Volume 3

Crowdsourcing Machine Learning for Buildings

Clayton Miller

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.

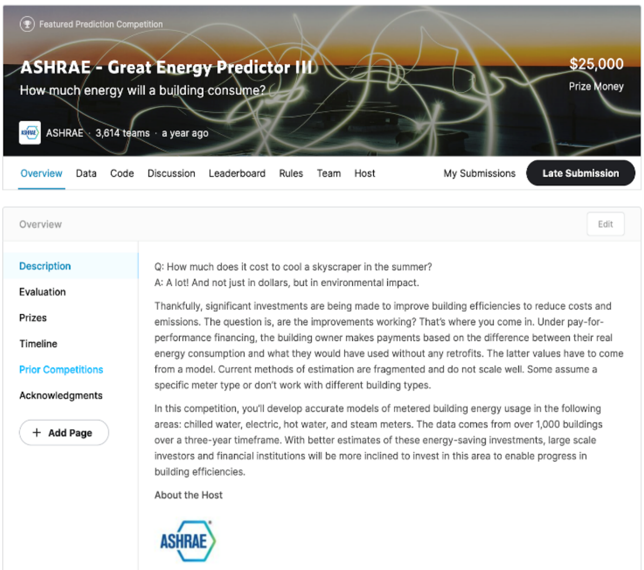

FIGURE 1 Screenshot from the GEPIII Kaggle competition description page

Dr. Clayton Miller, Co-Lead of Theme D and Assistant Professor at the National University of Singapore (NUS), and Dr. Pandarasamy Arjunan, a Post-Doc from Theme D at SBB2, led the technical effort to create such a ML competition for buildings. The Great Energy Predictor III (GEPIII) competition was an ASHRAE-hosted machine learning competition held in October through December 2019 focused on finding the best data-driven building energy prediction techniques. Much of the description of this event in this article is an adaptation of a Q&A from a recent ASHRAE Newsletter. The competition was held on the Kaggle platform, and participants were motivated by $25,000 worth of prize money supported by ASHRAE for the top five winners. Kaggle is the largest machine learning competition platform with over 5 million registered users and dozens of competitions per year from diverse fields such as advertising, medicine, marketing, and finance. Figure 1 shows a screenshot of the main landing page for the competition. The GEPIII competition was the first of its kind in building energy, and it attracted 4,370 participants, split across 3,614 teams from 94 countries who submitted 39,403 predictions. The competition planning was led by ASHRAE TC 4.7, with Chris Balbach leading the operational planning team that included Krishnan Gowri, Anthony Fontanini, and Jeff Haberl and with Dr. Miller in the lead of the technical planning team that included Dr. Arjunan as well as Anjukan Kathirgamanathan, June Young Park, and Zoltan Nagy.

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.

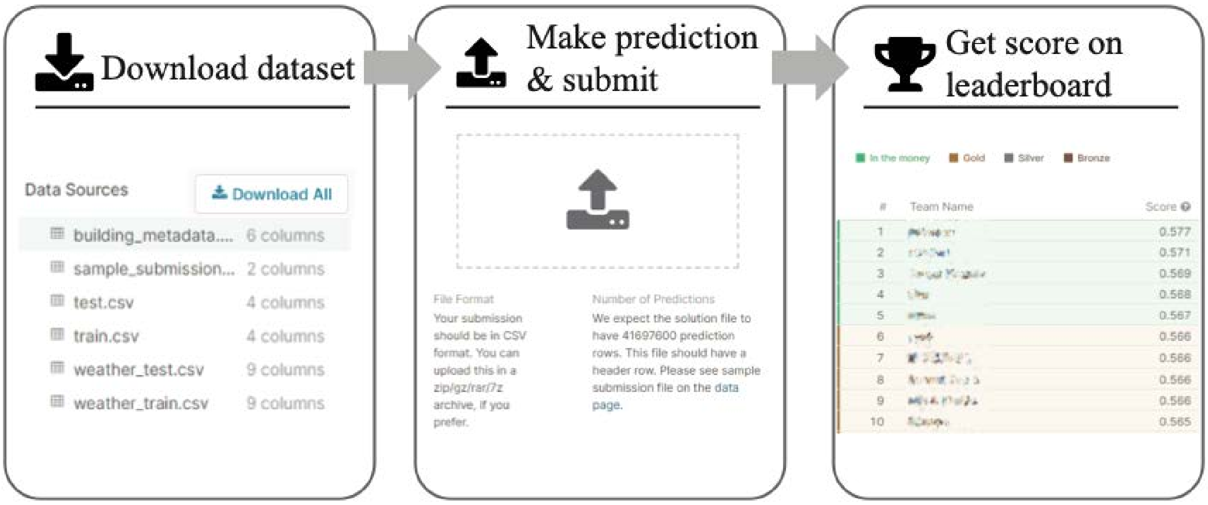

FIGURE 2 Overview of the ML competition process (Adapted from Miller et al. 2020a)

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).

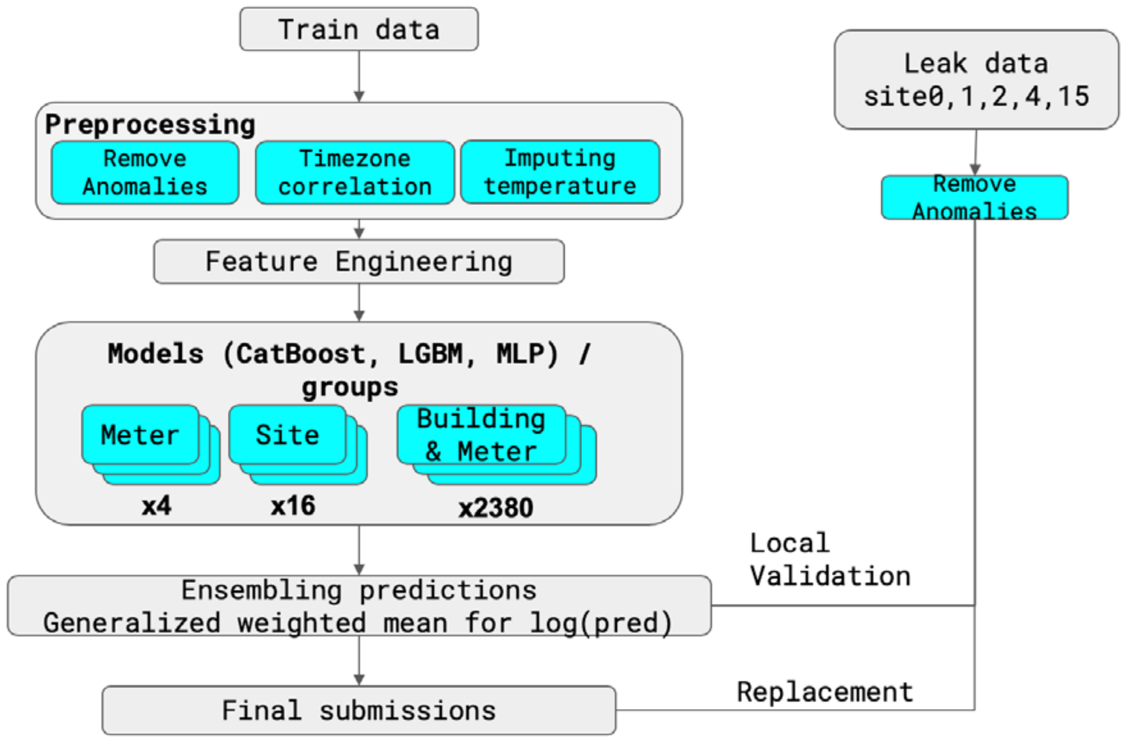

FIGURE 3 Overview of the structure of the first place winning team (Adapted from Miller et. al, 2020a)

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:

- ASHRAE 2020 Annual Meeting (Online) – Seminar 12 - Winners and Winning Solutions from the ASHRAE Great Energy Predictor III Machine Learning Competition – Jun. 2020
- ASHRAE 2020 Winter Meeting – Seminar 23 - The Great Energy Predictor Competition III - Feb. 2020
- ASHRAE 2019 Building Performance Analysis Conference – Denver, Colorado, USA - Data Science Meets ASHRAE: The Great Energy Predictor Shootout III - Sep. 2019
- ASHRAE 2019 Annual Meeting - Seminar 62 - Predictive Analytics for HVAC Engineers: What's in the Box? - Kansas City, MO, USA - The Great Energy Predictor Shootouts I and II: Revisited - Jun. 2019

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.

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Miller C, Arjunan P, Kathirgamanathan A, Fu C, Roth J, Park JY, et al. The ASHRAE Great Energy Predictor III competition: Overview and results. Science and Technology for the Built Environment. 2020a; 1–21. doi:10.1080/23744731.2020.1795514

Miller C, Kathirgamanathan A, Picchetti B, Arjunan P, Park JY, Nagy Z, et al. The Building Data Genome Project 2, energy meter data from the ASHRAE Great Energy Predictor III competition. Scientific Data. 2020b;7: 368. doi:10.1038/s41597-020-00712-x

Targeted occupant surveys: A novel method to effectively relate occupant feedback with environmental conditions

Thomas Parkinson and Stefano Schiavon

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.

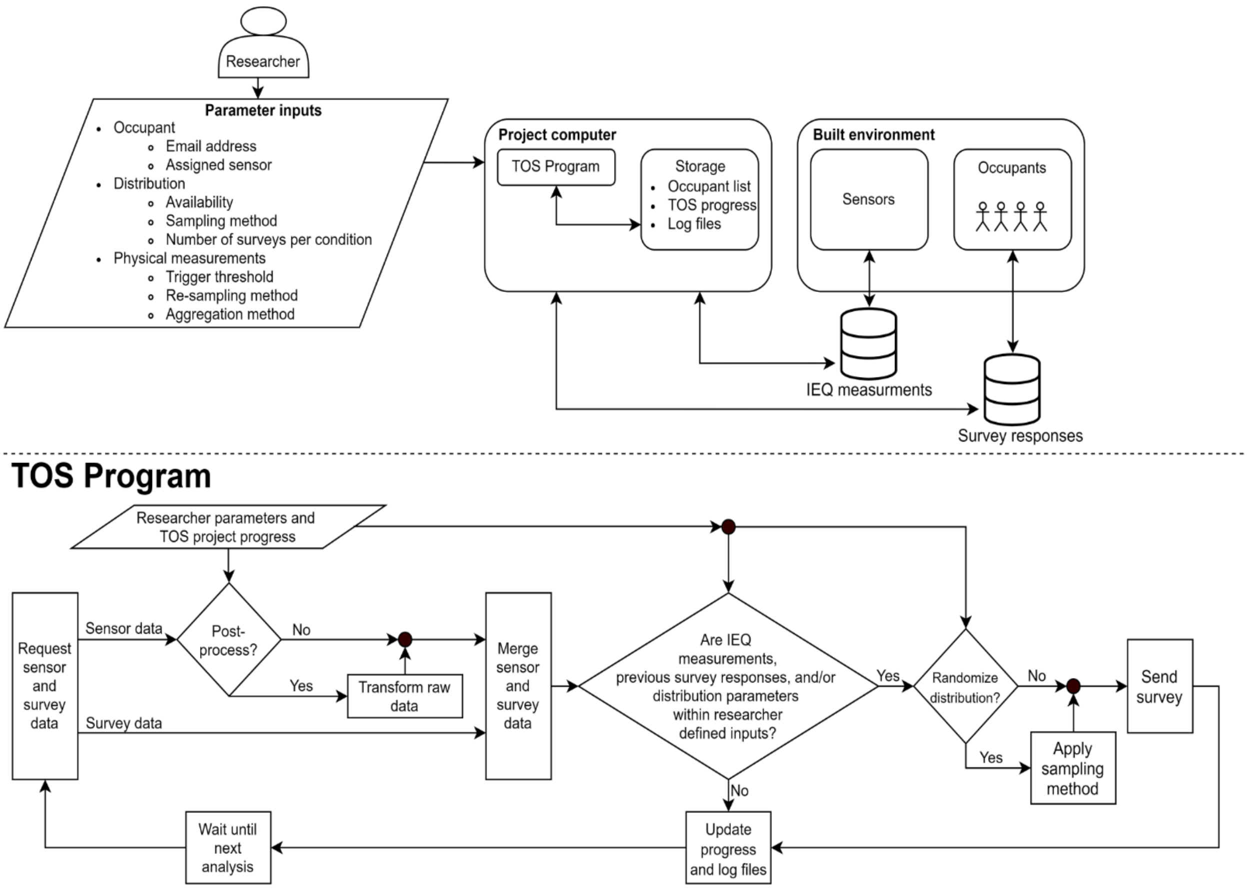


FIGURE 1 Targeted occupant survey (TOS) platform overview. The top schematic shows a high-level overview of how TOS projects are set up while the bottom schematic shows the TOS program flow.

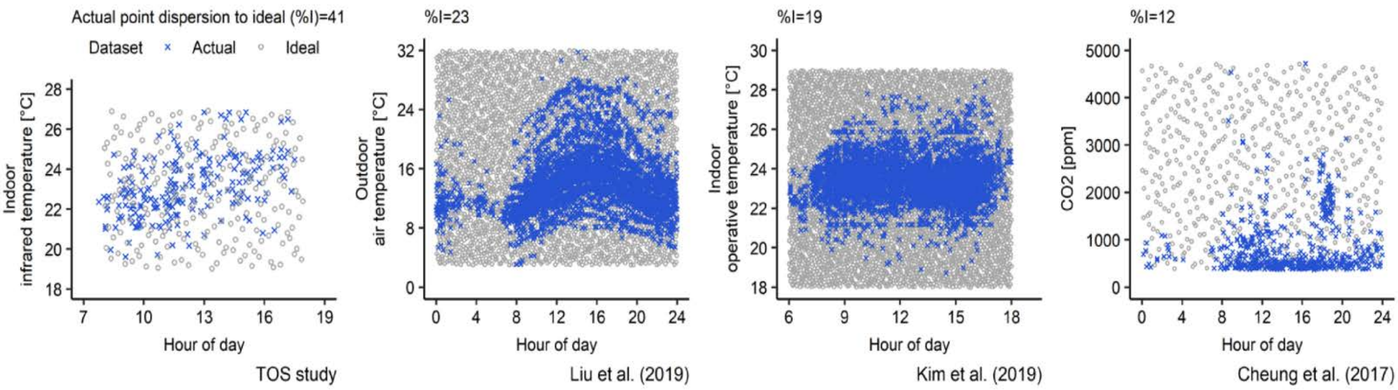


FIGURE 2 Visualization of point dispersion in actual datasets for our pilot study, Liu et al. (2019), Kim et al. (2019), and Cheung et al. (2017). Ideal datasets contain the same number of points as their respective actual dataset.

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

Duarte Roa, Carlos, Stefano Schiavon, and Thomas Parkinson. 2020. "Targeted Occupant Surveys: A Novel Method to Effectively Relate Occupant Feedback with Environmental Conditions." Building and Environment 184 (October): 107129. https://doi.org/10.1016/j.buildenv.2020.107129. Open-source version: https://escholarship.org/uc/item/9sj1c34p

SMART & ENERGY TECHNOLOGIES

Transactive Energy Market Framework for Decentralized Demand Management for Buildings



Rohit Chandra, Krishnanand Kaippilly Radhakrishnan, Sanjib Kumar Panda

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

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.

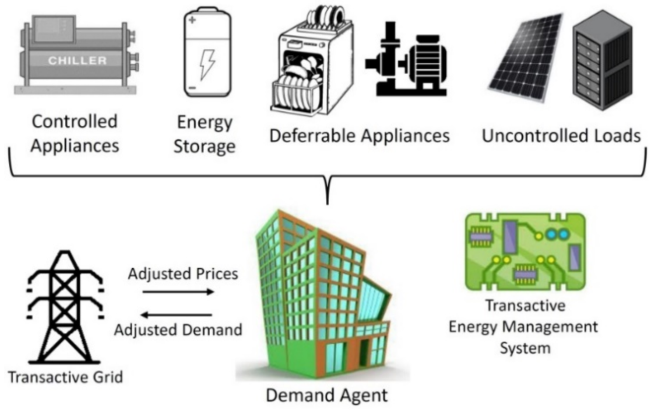


FIGURE 1 Representation of Energy Management Demand Agent (EMDA)

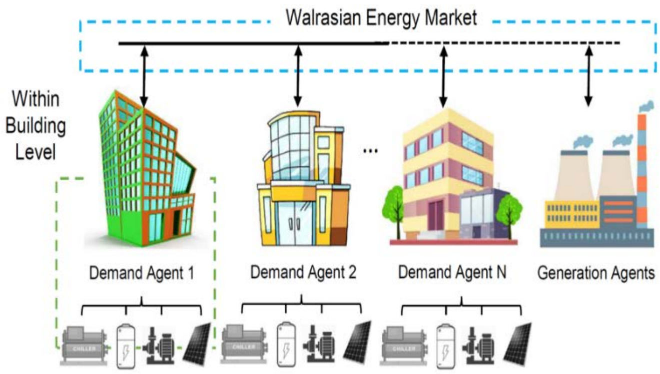


FIGURE 2 Hierarchical TE market proposal

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.

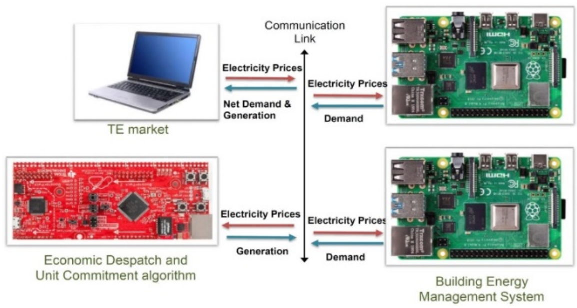


FIGURE 3 Hierarchical TE market proposal

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.

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

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

Reference

Chandra R. et al. Transactive Energy Market Framework for Decentralized Coordination of Demand Side Management within a Cluster of Buildings. IEEE Transactions on Industry Applications 2021.

A dimensionality reduction method to select the most representative daylight illuminance distributions

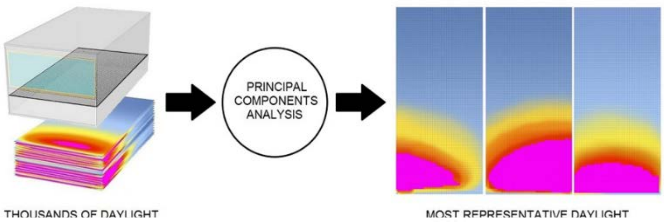
Stefano Schiavon and Michael Kent

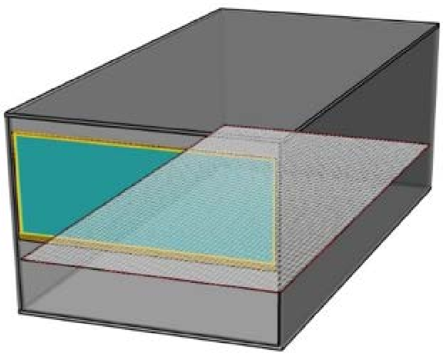
Climate-based annual daylighting simulations model the dynamic distribution patterns of natural light inside of buildings. These are communicated in research and practice as aggregate performance results. In practice, daylight distribution patterns on the horizontal plane – that represent workstation 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.

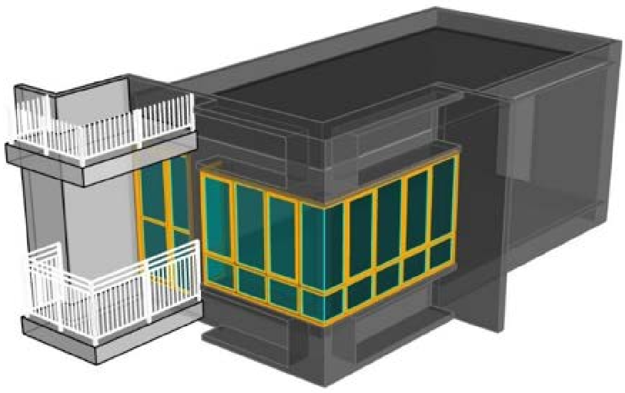
We used a widely utilised method of dimension reduction, known as principal components analysis. This reduced the daylight distribution patterns from the temporal conditions into a smaller number of principal components. Each principal component was used to derive a representative daylight distribution 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.





Simple "Shoebox" model

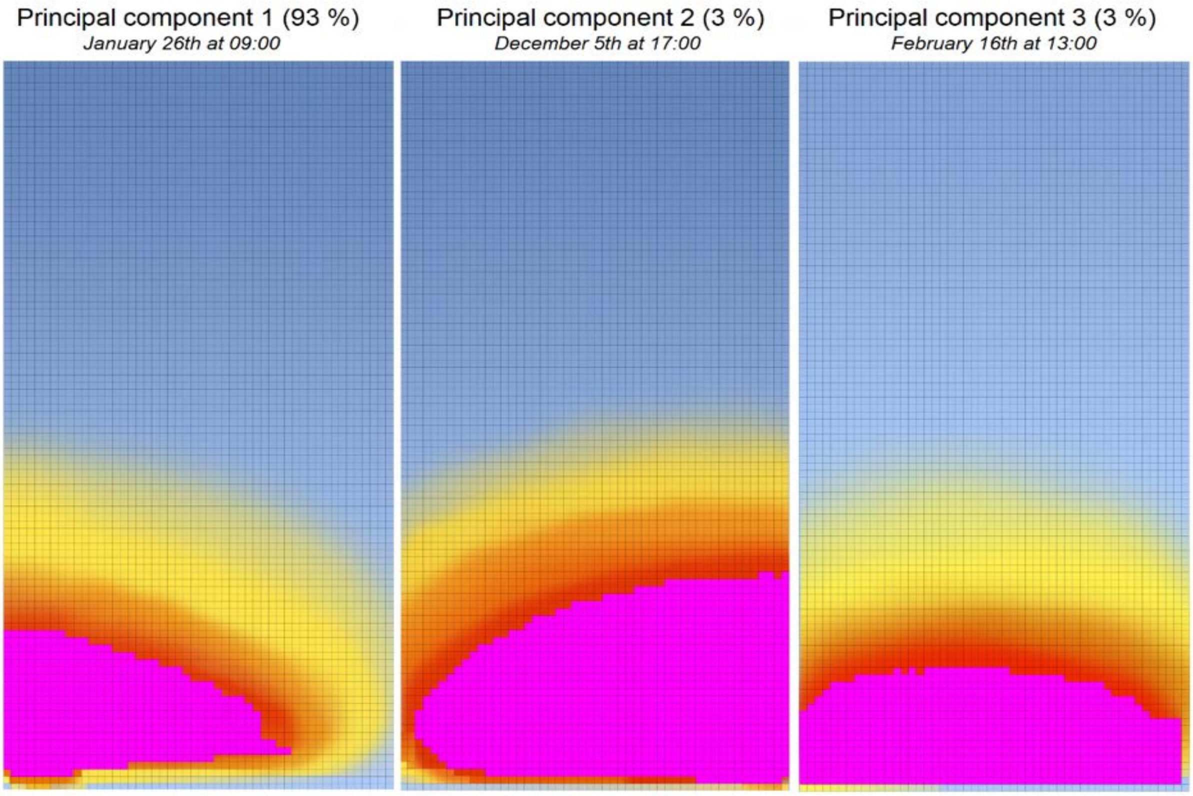


Complex model

Implementation of our approach in DIVA-for-Grasshopper is currently under development so that others will be able to make full use of this method in their own work. For more information see the reference below.

References

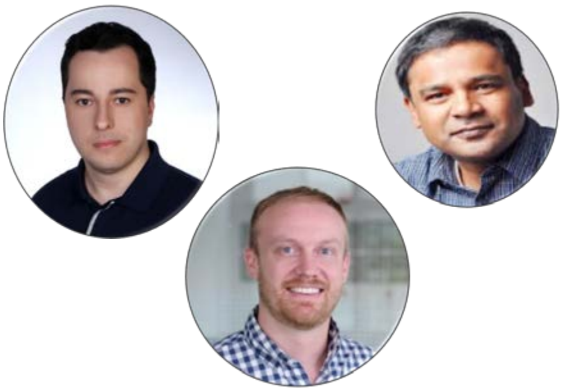
Kent MG, Schiavon S and Jakubiec JA. 2020. A dimensionality reduction method to select the most representative daylight illuminance distributions. Journal of Building Performance Simulation; 13:1, 122-135, 10.1080/19401493.2019.1711456.



Horizontal surface illuminances

AI AND MACHINE LEARNING

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.

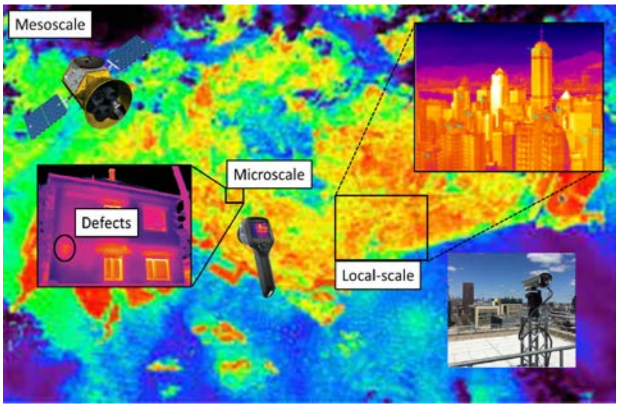


FIGURE 1 Infrared thermography at multiple scales of the built environment

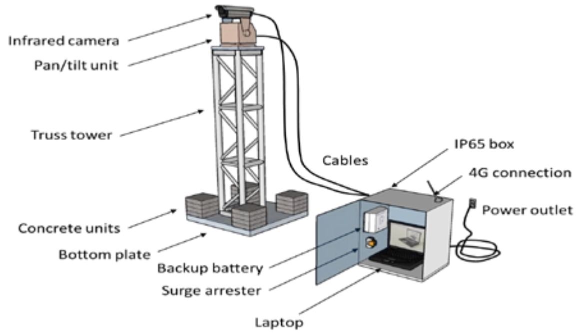


FIGURE 2 Observatory to be installed at the rooftop level in NUS campus

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.

FIGURE 3 Buildings in NUS campus to be observed by observatory at the roof-top over three months at least.

Electrical plug-load management

Krishnanand Kaippilly Radhakrishnan, Sanjib Kumar Panda

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.

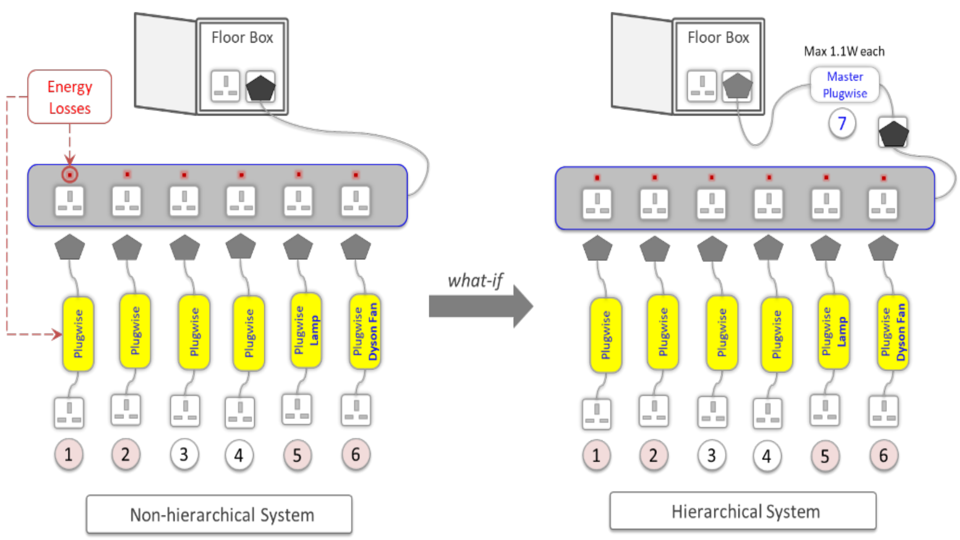


FIGURE 1 The non-hierarchical and hierarchical arrangements considered for the Plugwise devices in the living lab

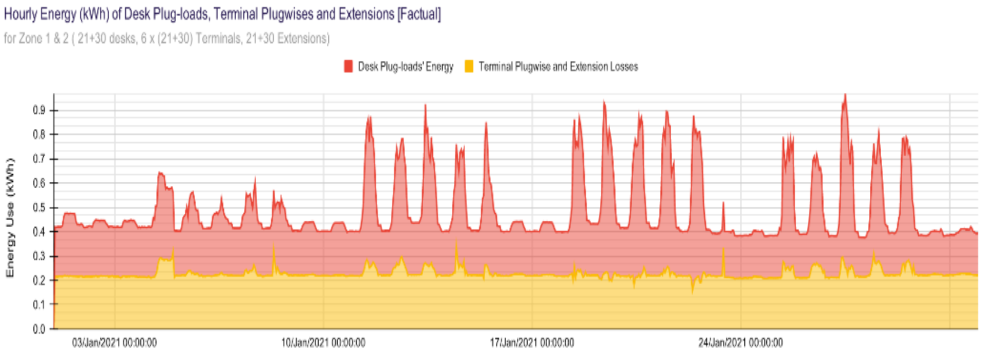


FIGURE 2 Hourly energy consumptions of desk plug-loads and losses due to the controlled energy delivery system (i.e. terminal Plugwise units and electrical extensions) using Jan2021 data

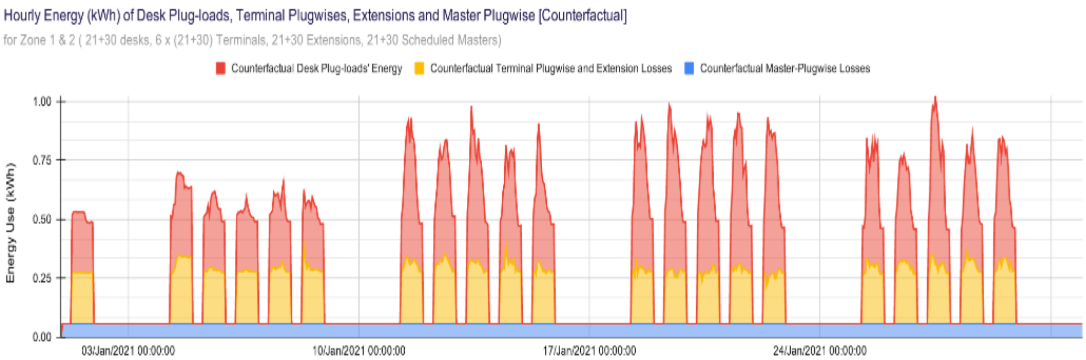


FIGURE 3 Hourly energy consumptions of desk plug-loads and losses due to the controlled energy delivery system (i.e. master Plugwise unit, terminal Plugwise units and electrical extensions) from counterfactual estimation based on Jan2021 data

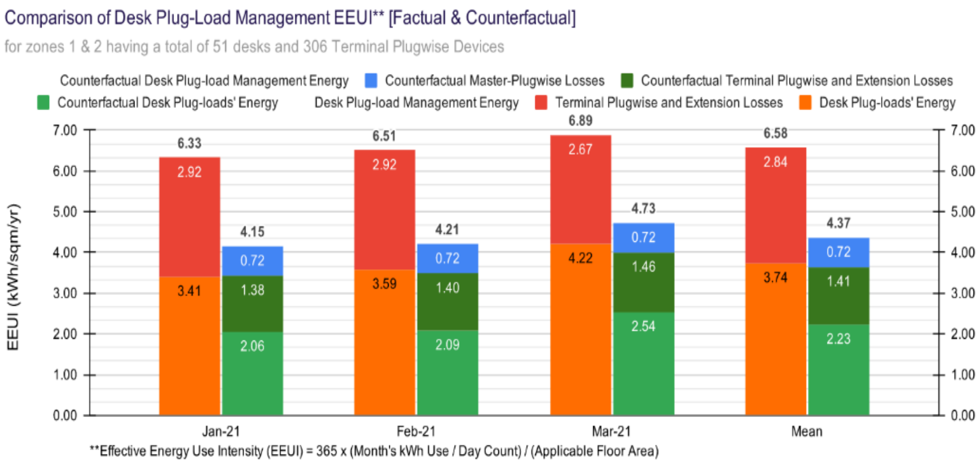


FIGURE 4 Changes in EEUI possible for each month in the desk plug-load consumption through the application of a hierarchical configuration and corresponding schedule

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

联合早报　　早 zaobaosg

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

建屋局受询时指出，在所经营的场所内接触点较多的范围，每天都会进行至少两次清洁与消毒。当局去年便已在有空调的场所使用滤网最低效率报告值为 14 等级的空气处理机组，可以更好地捕捉污染物颗粒，净化再循环空气。

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为减少冠病病毒传播，建屋发展局将探讨在现有的消毒和空气净化举措之上，采取更多措施，进一步加强旗下购物和办公场所的通风能力。

新加坡建设局、国家环境局和卫生部上个月25日更新了室内空气流通和空气质量技术性指导原则。建屋局就此答复《联合早报》询问时指出，在所经营场所内接触点较多的范围，每天都会进行至少两次清洁与消毒。

这些地方包括电梯大堂的按钮、自动扶梯的扶手，及入口处的门把手。当局也在入口处和电梯大堂放置搓手液，供访客使用。

除了包括大巴窑建屋局中心和兀兰民事中心在内的四座办公楼，建屋局也经营多达38个购物场所，包括百胜楼、文礼购物中心、万国广场和兀兰海军部村庄。

建屋局说，当局在政府去年5月发布第一份技术性指导原则之前，便已在有空调的场所使用滤网最低效率报告值（简称MERV）为14等级的空气处理机组，可以更好地捕捉污染物颗粒，净化再循环空气。

环境局已提醒所有业主采取有力措施维持卫生

当局过后也在空气处理机组中使用紫外线杀菌辐射（ultra-violet germicidal irradiation，简称UVGI）等空气净化技术。每天结束营业时，大楼也会把室内空气排出。

为了让空气更流通，电梯里的排风扇不间断运作，洗手间的排风扇则在场所营业时间之前的两小时开至最大。

另一方面，国家环境局上个月已向所有市镇理事会、小贩中心与巴刹业主、管理代理，以及保洁承包商及其职员发出通告，提醒他们采取有力措施，维持小贩中心和巴刹的清洁与公共卫生水平。

这些措施包括更长时间将洗手间排风扇开至最大，定时对洗手间里频繁接触的地方消毒，确保洗手液、厕纸、纸巾和烘干机等供应适当，及确保所有卫生器材和装置可完好运作。

商用地产业主也持续注意旗下商场的消毒与卫生措施。星狮地产零售业发言人答复询问时说，为了维持商场的室内空气质量，所有空调和通风系统都定期消毒。

此外，商场人流量高的地方也放置空气净化器，消除空中污染物和病毒。空调系统中的高效滤网也定期更换，增进空气流通与过滤。

研究：通风系统力度每添一成　大楼耗电增1%

建筑物的通风系统力度平均每增加一成，能源消耗就增加1%。

根据伯克利新加坡研究教育联盟（Berkeley Education Alliance Research in Singapore，简称 BEARS）研究中心热带建筑节能与可持续性（SinBerBEST）研究团队对本地商用大楼的初步研究数据，计算每平方公尺楼面一年耗电量的能耗指数（简称EUI），会随着通风系统力度加大而上升。若通风力度增加一倍，能耗也随之上升一成。

不过计算能耗的基数不仅限于通风系统本身，也包括大楼内的电灯、电梯等其他电力需求。

研究团队也发现，通风力度增加约三至五成时，系统本身产生的热能也会推高室内温度，影响楼内人员的热舒适度。因此，一味增加通风系统的力度未必是有效的解决方案。

SinBerBEST的首席研究员斯基亚翁（Stefano Schiavon）副教授说："如果一栋建筑已经符合新加坡的通风标准，也许就没有必要增加通风。我们应把注意力放在没有衔接到任何通风系统，或通风不佳的空间，这些地方的风险更高。"

紫外线杀菌辐射技术防生物膜形成有助节能

SinBerBEST项目总监祖莱米（Zuraimi Sultan）博士也说，空气处理机组若使用紫外线杀菌辐射（UVGI）技术，有助节省能源成本。"机组中灰尘和微生物的堆积，会对流入机组的空气形成阻力。UVGI可防止这层生物膜形成，使气流更顺畅，因此能稍微节省能源成本。"

亚历山大医院传染病科兼慢性疾病科副顾问医生孙锦受访时说，现有建筑物能通过保修空调系统、安装高效微粒空气（HEPA）过滤器等方法改善空气质量，未来的建筑则可在设计中融入通风孔，促进空气循环。

亚太临床微生物学与传染病学学会会长淡马亚教授认为，目前没有证据显示空中传播是冠病病毒传播的主要途径，通过气溶胶经空气传播的情况也属于少数。

"把过多的精力和金钱花在防止病毒通过空气传播上，可能分散我们在接种疫苗等真正重要事项上的注意力。"

不过，新加坡国立大学建筑系的詹德拉教授、张国伟副教授和谭国纬副教授在给本报的联名答复中提醒："打造更强的韧性势在必行，因为不采取足够措施的代价更高且不成正比。"

改善室内通风

冠病不会是人类面临的最后一场疫情。面对可能在人流较高或密闭空间传播开来的病毒，现有和未来的建筑物在设计上应采取哪些措施，降低公众染病的风险？

《联合早报》带你了解政府部门日前更新的建筑物通风指导原则概要，以及专家和学者对加强建筑物防疫韧性的建议。

有冷气及有机械通风功能的空间

- 确保通风系统良好运作，新鲜空气进气量调到最大
- 减少室内空气再循环
- 每天在人员进入前，把室内空气排出
- 将洗手间的排风扇开至最大

有冷气但不具备机械通风功能的空间

- 尽可能常打开门窗，同时应关闭或减少使用冷气
- 将洗手间的排风扇开至最大，也可考虑在窗上装置排风扇
- 确保排水系统无裂痕缝隙

自然通风场所

- 时时打开门窗
- 风扇置于窗前，向外吹风
- 将洗手间和厨房的排风扇开至最大，也可考虑在窗上装置排风扇
- 确保排水系统无裂痕缝隙

如何提高建筑物防疫韧性？

- 利用二氧化碳测量仪监测室内通风是否足够
- 在空气处理机组（Air Handling Unit，简称AHU）中使用紫外线杀菌辐射等技术
- 通风系统应具备空气排出功能，更换室内空气

资料来源／新加坡建设局、学者　　早报图表／张进培

学者：建筑通风率应可根据用途和人数灵活调控

在为建筑物制定室内空气质量管控方针时，应根据个别建筑物用途和活动进行设计和运作，把病毒通过空气传播的风险维持在可接受的水平以内。

39名来自不同国家的学者在科学期刊上联名发表以"应对室内呼吸道感染问题的范式转移"为题的论文，为提升建筑物的通风系统发出呼吁。

他们指出，以遏制传染为目标的通风率不应采用绝对值，而应该根据风险制定。未来的通风系统应保持灵活，根据需求而调控，比如为健身房设定相比电影院更高的通风率。

"建筑设计虽然应优化卫生和舒适度等方面的室内环境质量，但也应以具能源效率的方式进行，并考虑到当地气候和室外空气污染情况。"

学者们构想，未来的通风系统应有能力根据室内人数和所进行的活动自动调控通风率，并改善空气分布，向所需的区域输气，减少人员接触病毒的可能性，同时节省能源。楼内的显示仪也应显示实时的空气质量数据。

商用大楼使用前一小时应传输三倍容量室外空气

欧洲供暖、通风和空调协会联合会（简称REHVA）在4月推出的第四版指导原则中指出，鉴于近期研究证据显示冠病病毒可通过空气传播，学界也普遍认同冠病通过气溶胶发生远距离传播的理论，通风措施成为传染管控中最重要的工程调控工具。

REHVA建议，商用大楼在使用前一小时就应启动机械通风系统，向室内传输相等于室内空气三倍的室外空气。

美国疾病控制与预防中心于4月更新的办公大楼建议中也呼吁雇主改善楼内通风，包括提高室外空气占比、提高空气总输送量、考虑采用自然通风、改善中央空气过滤功能，及把空气过滤量尽可能调高。

2021年06月06日 星期日　　联合早报　　早 zaobaosg

政府更新建筑物通风守则　加强防疫韧性

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建筑物必须加强通风措施的把关，才能更具防疫韧性。政府将更新现有的建筑物机械通风及空调标准守则，加入冠病疫情期间大楼服务运作的实用措施，遏止病毒在建筑物内传播的风险。

拟议推出的守则包括，建议员工不要面对面就座。如果无法避免座位面对面，则应设立间隔。

为了加强通风，室外空气供应应调至最高。建筑物也应纳入排气（air purging）系统，业主应在人员每天进入前至少两小时进行排气；没有排气系统的大楼，则应将机械通风及空调系统的运作时间，提前至人员进入前两小时开始，至人员离开后两小时关闭。

负责定期检讨新加坡标准与技术参考的新加坡企业发展局（ESG）目前正探讨更新建筑物机械通风及空调系统标准守则（SS553），并从3月初至5月初进行公共咨询。当局也正检讨其他冠病相关的标准。

上述修改一旦采纳，将写入标准守则新增补的附录。附录题为"疫情中现有大楼服务运作的实用措施"，为今后建筑物如何在出现疫情时保持防疫韧性提供指导。

企发局发言人答复《联合早报》询问时说："有关修订的更多详情，包括如何推动业界采用新守则，以及其他冠病相关准则的修订详情，将在检讨工作完成后发布。"

除了检讨标准守则，政府也刚于上个月25日更新技术性指导原则，就如何改善建筑物内的空气流通和室内空气质量提出建议。

未来建筑设计上须兼备疫情和非疫情运作模式

如何防止冠病在密闭空间传播的课题也激起未来建筑应采取哪些设计元素的讨论。新加坡国立大学设计与环境学院建筑系室内空气质量研究组的詹德拉（Chandra Sekhar）教授、张国伟副教授和谭国纬副教授联合答复《联合早报》询问时说，未来的建筑在设计上必须至少能在疫情和非疫情模式之间切换。

"非疫情模式的设计和运作着重于可持续发展、低碳或碳中和运作，以及利用资源的效率；在疫情模式中则应转为保护和减缓病毒传播，结合预先设想的行政管控，提供适当防护。"

伯克利新加坡研究教育联盟研究中心的热带建筑节能与可持续性（SinBerBEST）研究团队受访时则说，未来建筑的设计应在应对通过空气传播的传染病方面更具韧性。

"在设计上应有更好或可调整的通风功能，在建筑阶段融入更好的消毒和过滤设施，以及研发新颖的建筑技术，让建筑物经受得起疫情的冲击。"

团队认为，未来设计的关键元素包括韧性、能源效率，以及保护楼内人员的健康和热舒适度。这具体可体现为对室内空气质量指标的更细微监测，如通过二氧化碳感应器让楼内人员检查是否需要加强通风。

建屋局办公楼和商场将加强通风　刊第4页

SinBerBEST

SinBerBEST, 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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