

# **Building Performance Analysis Conference and SimBuild 2018**

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American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)  
1791 Tullie Circle  
N.E. Atlanta, GA 30329  
USA

Phone: (404) 636-8400  
Fax: (404) 321-5478

[ashrae@ashrae.org](mailto:ashrae@ashrae.org)

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## Wednesday, September 26

Wednesday, September 26, 8:10 AM - 8:50 AM

### Keynote 1 (Intermediate)

#### **Yours, Mine and Ours: The Domain of Models and the Dogma of Professions**

Room: Continental AB

**Billie Faircloth, AIA, KieranTimberlake Associates, LLP, Philadelphia, PA**

In search of better building energy models, KieranTimberlake architects attempted to break down the energy modeling workflow. Working with energy modelers, they asked: What is the real purpose of an energy model? Who owns it? Why are energy modeling practices so difficult to change? And, what should we do about it now? They dissected the energy modeling workflow, looked for inefficiencies, and put the process back together again. Their task did not appear farfetched or unrealistic. They did, after all, accomplish a similar feat for life cycle assessment, an equally complex workflow. To date, KieranTimberlake's dream of a shared energy modeling workflow for designers and energy modelers remains unrealized. KieranTimberlake Partner and Research Director Billie Faircloth will recount her firm's attempt to prove that integrated energy modeling matters.

Wednesday, September 26, 9:45 AM - 11:00 AM

### Hybrid Session 1 (Intermediate)

#### **Software: New Tools and Workflows I**

Track: Tools and Techniques

Room: Salon A-1

Chair: Neal Krus, Ph.D., Member, Big Ladder Software, Denver, CO

We want to do more and be faster. The session informs attendees of new ways to use the breadth and depth of data and computing power at their disposal to do more with parametric analysis, urban-scale model creation, modular cloud-based models, and hardware & software-based speed increases. This is balanced by an example in a different direction: a simpler tool developed for regional use that produces results similar to general software.

**1. Big Data Analysis for High Performance Design...N/A**

*Amir Rezaei-Bazkiaei, Ph.D., Associate Member, CannonDesign, Amherst, NY*

**2. Automatic Building Detection and Energy Model Creation Technologies (AutoBEM)...N/A**

*Joshua New, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN*

**3. Tool for Energy Efficient Building Envelope Retrofitting (C001)...1**

*Bandana Jha<sup>1</sup> and Bishwajit Bhattacharjee<sup>2</sup>, (1)Indian Institute of Technology Delhi, New Delhi, India, (2)Indian Institute of Technology Delhi, India*

**4. Rapid Modeling of Large and Complex High Performance Buildings using EnergyPlus (C002)...9**

*Sagar Rao, David Conant-Gilles, Yiyuan Jia and Brittany Carl, Affiliated Engineers, Inc.*

**5. EnergyPlus Interior Radiant Heat Exchange Runtime Performance Improvements (C003)...17**

*Joshua New, Ph.D., Member and Mark B. Adams, Oak Ridge National Laboratory, Oak Ridge, TN*

9:45 AM - 11:00 AM

### Hybrid Session 2 (Intermediate)

#### **Designing for Daylighting**

Track: Case Studies

Room: Salon A-3

Chair: Lauren Wallace, The Epstein Group, Atlanta, GA

What an exciting session for daylighting aficionados to geek out on! First up, a look at the daylighting design of a tower building. Next up, a comparison of daylight and energy models of dynamic interior roller shades. Next a look at whether daylight savings time saves energy in the US. And finally, a field validation of daylighting performance in schools.

**1. Willis Tower Repositioned: The Glass Gridshell...N/A**

*Nicole Peterson, Thornton Tomasetti, Portland, ME*

**2. Dynamic Interior Roller Shades: Daylight and Energy Model Comparison with Experimental Data...N/A**

*Niraj Kunwar, Student Member, Iowa State University, Ames, IA*

### 3. Do Office Buildings 'Save' Energy in the United States due to Daylight Savings Time (DST)? A 50-State Simulation-based Study (C004)...21

*Tarek Rakha, Ph.D.<sup>1</sup>, Yuanyue Chen<sup>1</sup> and Christoph Reinhart, Dr.Ing.<sup>2</sup>, (1)Syracuse University, Syracuse, NY, (2)MIT, Cambridge, MA*

9:45 AM - 11:00 AM

### Hybrid Session 3 (Intermediate)

#### Envelope Modeling Strategies

*Track: Codes and Standards, Design Strategies*

*Room: Continental AB*

*Chair: Larry Froess, P.E., California Energy Commission, CA*

This session explores a number of envelope modeling issues including common misconceptions associated with computer-aided simulation and the dangers of overreliance on simulated data, the challenges of measuring envelope infiltration, the application of phase change materials (PCMs) for energy conservation, new approaches for insulation including cork aggregates and cement, and thermal storage as an effective method to regulate indoor temperature in residential high rise buildings.

#### 1. State of the Industry: Computer-Aided Simulation of High Performance Building Enclosures (C005)...29

*Sarah B. Rentfro and Anthony Nicasro, Simpson Gumpertz & Heger*

#### 2. Model-based Estimation of Building Infiltration (C006)...37

*Zhengwen Hao and Zheng O'Neill, Ph.D., P.E., Member, The University of Alabama, Tuscaloosa, AL*

#### 3. Testing and Modelling of Phase Change Materials for Building Applications...N/A

*Mark Richards, P.E., CPMP, Member, ASHRAE, San Diego, CA*

#### 4. Mechanical and Thermal Characterization of Cork Concrete Composite: Experimental and Modeling Study...N/A

*Boussetoua Hocine Sr., Dr.Ing., BEAP, Jijel University, Jijel, Algeria*

9:45 AM - 11:00 AM

### Hybrid Session 4 (Basic)

#### Codes: Compliance Strategies

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Dimitri Contoyannis, P.E., NORESCO, San Francisco, CA*

Case studies comparing various paths to compliance for different versions of Standard 90.1 are presented as well as the modeling and development process used to conduct the energy savings analysis of Standard 90.1. Also, case studies from several project types and climates are used to illustrate the benefits of a process for gauging code compliance, reducing peak loads, and reducing operational energy costs. Finally, a paper introduces simplified energy modeling (SEM) approaches using DOE2 and EnergyPlus and proposes a validation method for SEM.

#### 1. National Impact of ASHRAE Standard 90.1-2016 (C008)...45

*Bing Liu, P.E., Member<sup>1</sup>, Rahul Athalye, Associate Member<sup>2</sup> and Michael Rosenberg, Member<sup>3</sup>, (1)Northwest Energy Efficiency Alliance, Portland, OR, (2)PNNL, Richland, WA, (3)Pacific Northwest National Laboratory, Richland, WA*

#### 2. Choosing Your Own Compliance Path: Prescriptive vs. Performance...N/A

*Nathan Kegel, Associate Member, SMITHGROUP, Nashville, TN*

#### 3. How Do I Comply? Let Me Count the Ways...N/A

*John Bynum, Ph.D., Member, WSP USA, San Francisco, CA*

#### 4. A Simplified Energy Modeling Approach for Buildings (C009)...53

*Supriya Goel<sup>1</sup>, Chris Baker<sup>2</sup>, Doug Wolf<sup>2</sup>, Paul Henderson<sup>2</sup>, Nora Wang<sup>1</sup> and Michael Rosenberg, Member<sup>1</sup>, (1)Pacific Northwest National Laboratory, Richland, WA, (2)The Weidt Group*

9:45 AM - 11:00 AM

### Conference Paper Session 1 (Advanced)

#### Urban Scale Modeling

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Ralph Muehleisen, Ph.D., P.E., Member, Argonne National Laboratory, Lemont, IL*

This session includes several innovative approaches for urban scale modeling using unsupervised machine learning, data clustering, and optimization. One case study discusses the use of a computational clustering approach to model occupancy presence and the consequent energy load in residential buildings on an urban scale for a residential community in Austin, TX. by clustering available hourly energy use data. Another case study attempts to quantify the impact of windows sizes on the district energy simulation results and presents a new method for estimating window dimensions based on a statistical analysis of the Flemish Energy Performance Certificates database. Three software tools focusing on the application of machine learning for energy retrofit recommendations, PV array optimization and large scale simulations for urban scale energy modeling.

**1. Comparative Analysis of Machine Learning Algorithms for Building Archetypes Development in Urban Energy Modeling(C010)...60**

*Usman Ali, Student Member<sup>1</sup>, Mohammad Haris Shamsi<sup>1</sup>, James O'Donnell<sup>1</sup>, Fawaz Alshehri<sup>1</sup> and Eleni Mangina<sup>2</sup>, (1)University College Dublin, School of Mechanical & Materials Engineering, Dublin, Ireland, (2)University College of Dublin (UCD), Dublin, Ireland*

**2. Profiling Occupancy Patterns in Community-scale Residential Buildings using Data Clustering for Operational Energy Use (C011)...68**

*Rawad El Kontar, Student Member and Tarek Rakha, Ph.D., Syracuse University, Syracuse, NY*

**3. Estimating Window Dimensions of Residential Buildings in District Energy Models (C012)...76**

*Ina De Jaeger<sup>1</sup>, Yixiao Ma<sup>2</sup> and Dirk Saelens<sup>3</sup>, (1)EnergyVille / KU Leuven / VITO, Belgium, (2)EnergyVille / VITO, Belgium, (3)EnergyVille / KU Leuven, Belgium*

**4. An Intelligent Knowledge-based Energy Retrofits Recommendation System for Residential Building at an Urban Scale (C013)(P)...84**

*Usman Ali, Student Member<sup>1</sup>, Mohammad Haris Shamsi<sup>1</sup>, James O'Donnell<sup>1</sup>, Cathal Hoare<sup>1</sup> and Eleni Mangina<sup>2</sup>, (1)University College Dublin, School of Mechanical & Materials Engineering, Dublin, Ireland, (2)University College of Dublin (UCD), Dublin, Ireland*

**5. The PV Array Optimization Tools for the Urban-Scale Energy Modeling (C014)(P)...92**

*Jung Min Han, Student Member<sup>1</sup> and Christoph Reinhart, Dr.Ing.<sup>2</sup>, (1)Harvard University, Cambridge, MA, (2)MIT, Cambridge, MA*

**6. Modeling Building Energy Performance in Urban Context (C015)(P)...100**

*Xuan Luo and Tianzhen Hong, Ph.D., Member, LBNL, Berkeley, CA*

Wednesday, September 26, 11:15 AM - 12:15 PM  
**Team Case Study 1 (Intermediate)**

**Lessons Learned: Modeling Workflows**

*Track: Best Practice*

*Room: Continental AB*

*Chair: Gail Hampsmire, P.E., Green Business Certification Inc., Washington, DC*

Typical workflows in which engineers build energy models at the end of design stages often fall short of informing critical decisions that are made as designs evolve. This session presents two projects where shared energy models built by both the architectural and engineering teams positively influenced the outcome of such decisions. The first is a new low-energy veteran's nursing home that was informed by energy models from the earliest stages. The second project is a new inpatient hospital that employed early modeling to coordinate façade design with requirements for a low-energy HVAC system.

**1. Lessons Learned from Architect/Engineer Shared Energy Model Workflows...N/A**

*Chris Mackey, Payette Associates, Boston, MA*

11:15 AM - 12:15 PM  
**Hybrid Session 5 (Intermediate)**

**BIM Technology Nexus**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Chip Barnaby, Fellow ASHRAE, Retired, Lexington, MA*

This session provides an overview of ASHRAE Standard 224: BIM Specifications for Owners, its application and impact in standardizing the BIM data available to project teams. This session includes two case study presentations of life cycle cost

analysis (LCA) and integration of performance analysis tools using BIM. Best practice workflow for LCA is discussed using lessons learned from its adoption for sustainable materials selection for a new football stadium with retractable roof. A Gaze Visualizer tool integrating Radiance and Honeybee is presented for assisting designers effectively evaluate the impact of daylighting, glare intensity and visualize the results of lighting design decisions.

**1. Standard 224: BIM Specifications for Owners...N/A**

*M. Knight, P.E., BEMP, Fellow ASHRAE, Whole Building Systems, LLC, Charleston, SC*

**2. Using BIM Tools for Life Cycle Assessment of Large Buildings...N/A**

*Brian McKinney, BEMP, Member, BuroHappold Engineering, New York, NY*

**3. A Gaze Visualizer Tool: Implementation of Gaze Data into Lighting Rendering Tools Using Radiance and Honeybee for Grasshopper3D (C016)...107**

*Mandana Sareykhanie<sup>1</sup>, Susanne Vinther Kjærsgaard<sup>1</sup>, Mia JohnsenHee Korsbæk Johnsen<sup>1</sup>, Jan Wienold, Dr.Ing.<sup>2</sup>, Kristoffer Negendahl<sup>1</sup> and Marilynne Andersen, Ph.D.<sup>3</sup>, (1)Technical University of Denmark DTU, Department of civil engineering, Building and Energy Section, Denmark, (2)Laboratory of Integrated Performance in Design (LIPID), École Polytechnique Fédérale de Lausanne (EPFL), CH, (3)École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland*

**11:15 AM - 12:15 PM**  
**Hybrid Session 6 (Basic)**

**Codes: It's Hot in California**

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Rahul Athalye, Associate Member, Energy-Solution*

California's Title 24 Part 6 is a statewide code, which is considered to be as stringent, or even more stringent than the national model codes. In this session, you will learn about the exciting developments in the future of Title 24's performance path, customized compliance workflows, and where the next generation of savings might come from for California.

**1. Dogs and Cats Living Together: ASHRAE 90.1 in California?...N/A**

*Dimitri Contoyannis, P.E., Member, NORESO, San Francisco, CA*

**2. Behind the Scenes of California Compliance Modeling: A Custom Workflow to Help Ease the Pain...N/A**

*Greg Collins, P.E., BEMP, Member, Zero Envy, Santa Monica, CA*

**3. Changing California Code: Finding the Next Savings Opportunities (C017)...113**

*Jared Landsman, Stefan Gracik, Ken Takahashi and Ryan Sit, Integral Group, Oakland, CA*

**11:15 AM - 12:15 PM**  
**Hybrid Session 7 (Intermediate)**

**Daylighting I**

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Nicole Peterson, Thornton Tomasetti, Portland, ME*

This session presents a virtual reality daylighting design tool developed to enhance user awareness and improve visual accuracy in early decision-making stages. Also, papers address: techniques and applications of deep neural networks in daylighting simulations and measurements to predict long-term daylighting performance from short-term data collection, the status of new hybrid simulation for daylight analysis method under development, and a new control strategy to manage the state of electrochromics with the intent to improve daylight performance and energy efficiency simultaneously.

**1. RadVR: A Virtual Reality Daylighting Design Tool...N/A**

*Mohammad Keshavarzi, Student Member, University of California Berkeley, Berkeley, CA*

**2. Computing Long-term Daylighting Simulations from High Dynamic Range Imagery Using Deep Neural Networks (C018)...119**

*Yue Liu, Student Member<sup>1</sup>, Alex Colburn<sup>2</sup> and Mehlika Inanici<sup>3</sup>, (1)University of Washington, College of Built Environments, Seattle, WA, (2)Zillow Group, Seattle, WA, (3)University of Washington, Seattle, WA*

**3. Hybrid Simulation for Daylighting of Complex Fenestration Systems for Building Envelopes (C019) (P)...127**

*Kemal Celik<sup>1</sup>, Alex Mead<sup>2</sup> and Mosalam Khalid<sup>2</sup>, (1)New York University Abu Dhabi, Abu Dhabi, United Arab Emirates, (2)University of California, Berkeley, CA*

**4. Development of a Comparison-Based Control Strategy of Electrochromic Glazing for the Management of Indoor Lighting and Energy Efficiency (C020) (P)...133**

*Maryam Hamidpour, Ph.D. and Vincent Blouin, Ph.D., Clemson University, Clemson, SC*

11:15 AM - 12:15 PM

**Seminar 1 (Intermediate)**

**LCA Has a Midlife Crisis: Life Cycle Analysis Stories from the Profession**

*Track: Case Studies*

*Room: Salon A-3*

*Chair: Vikram Sami, OLSON KUNDIG, Seattle, WA*

Predicting embodied energy and carbon life cycle assessments in new construction have been an aspiration of architectural design teams for decades. The basic science has been available with tools like BEES and the Athena Life Cycle Calculator, but older versions of these tools and methods to use them were onerous and it was hard to get an effective prediction. With advances in newer tools, some of which tie in to BIM platforms, embodied energy assessments have never been more accessible to architects. In this session, 3 practitioners will describe how their firms are currently engaging with Life Cycle Assessments for projects.

**1. What Does it Take to Develop and Maintain an LCA Tool?...N/A**

*Ryan Welch, KieranTimberlake Associates, LLP, Philadelphia, PA*

**2. How Does Design Change When You Integrate LCA into Your Design Decisions?...N/A**

*Z Smith, Eskew + Dumez + Ripple, New Orleans, LA*

**3. LCA Assessment and Embodied Carbon Accounting...N/A**

*Jim Newman, Linnean Solutions, Cambridge, MA*

Wednesday, September 26, 1:45 PM - 3:00 PM

**Hybrid Session 8 (Advanced)**

**Fenestration Modeling**

*Track: Best Practice*

*Room: Continental AB*

*Chair: Susan Collins, Whole Building Systems, Charleston, SC*

As modeling for daylighting evolves and strategies emerge to understand the impact of circadian lighting on occupant comfort and wellbeing, a number of studies have been undertaken. This session highlights a number of explorations including measuring and modeling lighting in the spaces with ElectroChromatic windows, an analysis of light in Skylight and Clerestory Design, the influence of external shading on heat transfer coefficients, and defining parameters and metrics to build a composite understanding of predicted, hourly circadian light in an office space.

**1. A Workflow for Assessing Circadian Daylight Performance of the Electrochromic Glazing...N/A**

*Ahoo Malekafzali Ardakan, Ph.D., SageGlass, Salt Lake City, UT*

**2. Outcome-Based Design for Circadian Lighting: An Integrated Approach to Simulation & Metrics (C021)...141**

*Martin Timothy Brennan, AIA and Alex Robert Collins, ZGF Architects LLP*

**3. Modeling an Electrochromic Window Using a Multi-criteria Control Strategy (C022)...149**

*Ranojoy Dutta, HBDP and BEMP, Associate Member, View Inc, Milpitas, CA*

**4. Sensitivity Analysis of Skylight and Clerestory Design on Energy and Daylight Performance of a Retail Building (C023)...157**

*Yuan Fang<sup>1</sup> and Sooyeon Cho, Ph.D., Member<sup>2</sup>, (1)1: Western Kentucky University, (2)North Carolina State University, Raleigh, NC*

**5. Influence of External Shadings on Convective Heat Transfer Coefficients for a High-Rise Building (C024) (P)...165**

*Meseret Kahsay<sup>1</sup>, Girma Bitsuamlak<sup>2</sup> and Fitsum Tariku<sup>3</sup>, (1)UWO, London, ON, Canada, (2)University of western Ontario, Canada, (3)British Columbia Institute of Technology (BCIT), Burnaby, BC, Canada*

1:45 PM - 3:00 PM

**Hybrid Session 9 (Intermediate)**

**Net-Zero Design Strategies**

*Track: Case Studies*

*Room: Salon A-3*

Chair: Annie Marston, Ph.D., Hurley Palmer Flatt, London, United Kingdom

This session focuses on how statistical energy demand data from existing Net Zero Energy buildings could help designers develop strategies to model their buildings. It also reveals how actual energy performance of the building may differ from modelled data. Some cases of retrofit office spaces, schools etc. are discussed. Importance of conducting audits of existing energy demand and using that information as inputs in the energy model are also examined.

**1. Getting to Net Zero (Revised)...N/A**

*Eric Dixon, P.E., BEMP, SmithGroup, Washington, DC*

**2. Setting a Zero Net Energy Workflow Paradigm for Strategic Planning and Target Setting...N/A**

*Sananda Mukherjee, AECOM, Anaheim, CA*

**3. Performance Modeling as Design Driver for establishing Net Zero Design Guidelines...N/A**

*Shona O Dea, BEMP, Associate Member, DLR Group, Chicago, IL*

**4. Lessons Learned from Pursuing ZNE Retrofits for Municipal Facilities through BayREN Program...N/A**

*Yung Nguyen, BEMP, Associate Member, DNV GL, San Diego, CA*

1:45 PM - 3:00 PM

**Hybrid Session 10 (Intermediate)**

**Looking into the Crystal Ball: Future of California Code Compliance**

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Abhijeet Pande, Member, TRC, Oakland, CA*

There is a lot happening in the California code compliance world. From the move to a stable and independent baseline akin to Appendix G in 90.1-2016, to using a database of EUIs for utility incentive programs, to the California Energy Commission's focus in the upcoming years on new features and developments in software-based code compliance. We have invited a group of speakers from the California code compliance world that will make this an informative and engaging discussion. If you are interesting in code compliance, this is the session for you!

**1. California Energy Commission: State of California's current efforts in Compliance Energy Modeling...N/A**

*Larry Froess, P.E., California Energy Commission, CA*

**2. Site to Source Energy Metrics SCE : EUI Table – Database for Energy Comparisons and Use in Incentive Programs for Utilities...N/A**

*Charles Kim, P.E., Southern California Edison, Rosemead, CA*

**EUI Tables...N/A**

*Ryan McFadyen, CP&S, Rosemead, CA*

**Multifamily Modeling/Prototypes...N/A**

*Dallen Coulter, Southern California Edison, Rosemead, CA*

**3. Development of Fixed Baseline in CBECC-Com...N/A**

*Dimetri Contoyannis, P.E., Member, NORESKO, San Francisco, CA*

**Compliance Software in Design Workflow...N/A**

*Greg Collins, P.E., BEMP, Member, Zero Envy, Santa Monica, CA*

1:45 PM - 3:00 PM

**Hybrid Session 11 (Basic)**

**Lessons Learned: Model Accuracy and Reliability**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Gail Hampsmire, P.E., Green Business Certification Inc., Washington, DC*

This session brings together four case studies and strategies for improving model quality and reliability. A summary of LEED model review by thirdparty reviewers is presented providing insights into trends in errors that lead to large gaps in initial predicted versus final approved energy model performance. Comparative evaluation of white-box, grey-box and black-box modeling techniques are used to highlight the advantages and drawbacks in terms of accuracy, flexibility and robustness.

**1. A Meta-analysis of Energy Modeling Errors: Learn from Others Mistakes...N/A**

*Gail Hampsmire, P.E., BEMP, Member, GBCI, Washington DC, DC*



## 2. Quality Control for Energy Models...N/A

*Oliver Baumann, CPMP, Member, Baumann Consulting, Inc., Chicago, IL*

## 3. Comparative Analysis of White-Box, Gray-Box and Black-Box Models for Thermal Simulation of Indoor Environment: Campus Building Case Study (C025)...173

*Muhyiddine Jradi, Ph.D.<sup>1</sup>, Krzysztof Arendt<sup>2</sup>, Hamid Reza Shaker<sup>2</sup> and Christian Veje<sup>2</sup>, (1)University of Southern Denmark, Odense, Denmark, (2)University of Southern Denmark, Denmark*

## 4. Renewed Perspectives on Energy Modeling: 4 Insights from a Millennial...N/A

*Sigal Shemesh, BuroHappold Engineering, New York, NY*

1:45 PM - 3:00 PM

### Conference Paper Session 2 (Intermediate)

## Occupant Comfort Modeling I

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Susan Collins, Whole Building Systems, Charleston, SC*

Health and Wellness are the new buzz words in high performance buildings. Learn how the influence of solar radiation and air flow from ceiling fans affects indoor thermal comfort and how indoor environmental conditions can influence comfort, productivity and health. Hear research results from experiments on actual occupants and a case study on post occupancy evaluations (POE) that draws on quantitative (sensor readings), qualitative (occupant surveys) and a real-time web IoT (Internet of Things) dashboard.

### 1. A New Modeling Approach for the Assessment of the Effect of Solar Radiation on Indoor Thermal Comfort (C026)...181

*Andrea Zani, Ph.D.<sup>1</sup>, Andrea Giovanni Mainini<sup>1</sup>, Edward Arens<sup>2</sup>, Stefano Schiavon<sup>2</sup> and Juan Blanco Cadena<sup>1</sup>, (1)Politecnico di Milano, Italy, (2)University of California Berkeley, Berkeley, CA*

### 2. Prediction of Improved Occupant's Thermal Comfort with Ceiling Fan through Coupled Energy Simulation and Computational Fluid Dynamics (C027)...189

*Brijesh Pandey<sup>1</sup>, Atul Sharma<sup>2</sup> and Rangan Banerjee<sup>3</sup>, (1)IIT Bombay, Department of Energy Science & Engineering, Mumbai, India, (2)IIT Bombay, Bombay, India, (3)IIT Bombay, Department of Energy Science & Engineering, India*

### 3. Transient 3-D Modeling of Ceiling Fans using CFD for Achieving Thermal Comfort (C028)(P)...197

*Yatheshth Anand, Ph.D.<sup>1</sup>, Shubham Kumar Verma<sup>1</sup> and Sanjeev Anand<sup>2</sup>, (1)Shri Mata Vaishno Devi University, Katra, India, (2)SMVD University, Katra, India*

### 4. Case Study of Occupants' Adaptation on Different Thermal Conditions in Indoor Environment and its Energy Savings Potential (C029)(P)...205

*Alzbeta Kohoutková<sup>1</sup>, Jana Horváthová<sup>2</sup>, Martin Kny<sup>2</sup> and Nehasil Ondřej<sup>2</sup>, (1)CTU in Prague, University Centre for Energy Efficient Buildings, Prague, Czech Republic, (2)CTU in Prague, University Centre for Energy Efficient Buildings, Czech Republic*

### 5. The Development of an Indoor Environmental Monitoring Framework for Post-Occupancy Evaluation using Real-time Sensor Web-tools (C030)(P)...213

*Nada Tarkhan, Arup, Boston, MA*

Wednesday, September 26, 3:30 PM - 5:00 PM

### Hybrid Session 12 (Basic)

## Early Design Modeling I

*Track: Best Practice*

*Room: Continental AB*

*Chair: Saranya Gunasingh, Seventhwave, Chicago, IL*

Early design decisions can resonate for decades, but time and information may be scarce. This session describes early design tools for three spatial levels. A neighborhood-level tool examines the interdependence of energy, transportation, and communication systems. Three building-level tools include an evolutionary algorithm that melds energy with aesthetics, a study of space influences on occupant behavior in public settings, and rapid assessment of basic geometry on energy use. Finally, the session describes tools for system-level design: methods for residential earth ducts, relationship between glazing and daylighting/conditioning energy/first cost, and practitioner-focused natural ventilation design in early and late stages.

### 1. A Method for Incorporating Aesthetic Variables and Form Diversity into Architectural Design Optimization...N/A

*Shermeen Youisif, Member, Texas A&M University, College Station, TX*

**2. Data Analytics: Saving Much More Than Energy...N/A**

*Kevin Day, P.E., Member, MBP, Raleigh, NC*

**3. Glazing in Commercial Buildings: The Balance between Cost and Energy Consumption (C031)...221**

*Jennifer L. Williamson, P.E.<sup>1</sup>, Tat Fu, Ph.D., P.E., BEMP<sup>2</sup>, Brent Gabby<sup>1</sup>, Jenna Testa<sup>1</sup> and Chen Hu<sup>1</sup>, (1)Simpson Gumpertz & Heger, (2)Simpson Gumpertz & Heger, Waltham, MA*

**4. The Role of Space Design in Energy Prediction of Multi-functional Spaces in Public Buildings (C032)...229**

*Rima Alaaeddine, Elham Del Zendeh and Song Wu, University of Huddersfield, United Kingdom*

**5. Exploring Geometric Sensitivity using Rapid Energy Performance Simulation (C033) (P)...237**

*Timothy Hemsath and Joel Yow, HDR*

**6. Modeling Natural Ventilation in Early and Late Design Stages: Developing the Right Simulation Workflow with the Right Inputs (C034) (P)...242**

*Maria Alejandra Menchaca Brandan<sup>1</sup> and Alonso Dominguez Espinosa<sup>2</sup>, (1)Thornton Tomasetti, (2)Arup*

**7. Modeling of Smart Community Infrastructure Accounting for the Interdependencies Among Energy, Transportation and Communication Networks (C035) (P)...250**

*Wangda Zuo, Ph.D., Member, Xing Lu and Yangyang Fu, University of Colorado Boulder, Boulder, CO*

3:30 PM - 5:00 PM

**Hybrid Session 13 (Intermediate)**

**Occupant Comfort Modeling II**

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Lauren Wallace, The Epsten Group, Atlanta, GA*

Take a look at occupant comfort that goes beyond air and ASHRAE 62.1, plus specifics on technology used to analyze occupant comfort across multiple realms. This session covers occupant in terms of thermal comfort from multiple view points, but we will also cover topics that include acoustics, indoor air quality, and visual comfort for occupants.

**1. Exploring Thermal Comfort Acceptance Criteria in Energy Modeling (C036)...258**

*Elvin Ruya<sup>1</sup> and Godfried Augenbroe<sup>2</sup>, (1)Bractlet Inc, Austin, TX, (2)Georgia Institute of Technology, Atlanta, GA*

**2. The Disconnect Between Legacy Occupancy Schedules and Ventilation Design Occupant Densities or How Many Spaces Can One Person Occupy?**

*Fred Porter, NORESKO Sustainability Services, Boulder, CO*

**3. A Calibration and Adjustment Method for a Dynamic Visual Comfort Assessment (C037)...266**

*Henry Skates<sup>1</sup>, Zahra Hamedani<sup>1</sup>, Ebrahim Solgi<sup>1</sup>, Ruwan Fernando<sup>1</sup> and Mandana Sarey Khanie<sup>2</sup>, (1)Griffith University, Australia, (2)Technical University of Denmark DTU, Department of civil engineering, Building and Energy Section, Denmark*

**4. Aeroacoustic Facade Noise: Predicting Wind-Induced Noise from Perforated Facade Panels (C038)...274**

*Nathaniel Jones, Ph.D., Associate Member and Alexej Goehring, P.E., Arup, San Francisco, CA*

**5. Considerations for the Design and Energy Modeling of New Commercial Buildings with Increased Ventilation Rates (C039)(P)...282**

*Caroline Traube, P.E., BEMP, Member and Skander Spies, McKinstry, Seattle, WA*

**6. Assessing Indoor Concentrations of Formaldehyde in Single-Detached Canadian Households Due to Oriented Strand Board (OSB) Wall Sheathing (C040) (P)...290**

*Matthew David Baffa<sup>1</sup> and David Raymond Wach<sup>2</sup>, (1)Building Sciences Inc., Concord, ON, Canada, (2)Engineering Link Incorporated*

**7. Development of an Empirical Method for Calculating Discharge Coefficients for CONTAM Models (C041) (P) ...298**

*Yichun Huang, Ph.D., Hao Zhou, Student Member, Gavin Xue and Chen Chen, EMSI, Shanghai, China*

3:30 PM - 5:00 PM

**Hybrid Session 14 (Advanced)**

**To Script or Not to Script?**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Amir Roth, US Department of Energy, Washington, DC*

Papers cover: a review of tools and techniques from the software engineering world, such as automatic document generation, automatic chart generation and build automation, applied to modeling work to achieve greater

productivity; the application of a set of common modeling tasks, such as design optimization, LEED modeling and measure analysis, on prototype buildings applied to four scripting frameworks for EnergyPlus to show how each system is used in practice; and a description of the refactoring efforts around the EnergyPlus input processor to natively support JavaScript Object Notation. Other presentations: a python utility which leverages the Functional Mock-up Interface open standard to support the interoperability of building simulation tools; and a workflow that integrates an energy model with a customized python script to optimize the chilled water plant operation of a science lab building in San Francisco.

**1. Model Like a Programmer 2: More Tools and Techniques for Greater Productivity (C042)...304**

*Michael O'Keefe and Peter Ellis, Member, Big Ladder Software, Denver, CO*

**2. Scripting Frameworks for Enhancing EnergyPlus Modeling Productivity (C043)...312**

*Amir Roth<sup>1</sup>, Jamie Bull<sup>2</sup>, Scott Criswell, Member<sup>3</sup>, Peter Ellis, Member<sup>4</sup>, Jason Glazer, P.E., Member<sup>5</sup>, David Goldwasser<sup>6</sup>, Neal Kruis, Ph.D., Member<sup>4</sup>, Andrew Parker<sup>7</sup>, Santosh Philip<sup>8</sup> and David Reddy, Member<sup>9</sup>, (1)US Department of Energy, Washington, DC, (2)oCo Carbon Ltd, London, United Kingdom, (3)SAC Software Solutions LLC, Portland, OR, (4)Big Ladder Software, Denver, CO, (5)GARD Analytics, Inc., Arlington Heights, IL, (6)NREL, (7)National Renewable Energy Laboratory, Golden, CO, (8)Loisos + Ubbelohde, Alameda, CA, (9)360 Analytics, Seattle, WA*

**3. EnergyPlus Performance Improvements Via JSON Input Refactoring (C044)...320**

*Joshua New, Ph.D., Member and Mark B. Adams, Oak Ridge National Laboratory, Oak Ridge, TN*

**4. Simulator To FMU: A Python Utility to Support Building Simulation Tool Interoperability (C045)...325**

*Michael Wetter, Ph.D., Member<sup>1</sup> and Thierry Stephane Nouidui, Ph.D.<sup>2</sup>, (1)Lawrence Berkeley Lab, Berkeley, CA, (2)Lawrence Berkeley National Laboratory, Berkeley, CA*

**5. Integrating Energy Model with a Customized Script to Optimize Building Operation...N/A**

*Te Qi, BEMP, Atelierten, san francisco, CA*

3:30 PM - 5:00 PM

**Hybrid Session 15 (Advanced)**

**CFD and Visualization to the Rescue**

*Track: Case Studies*

*Room: Salon A-3*

*Chair: Rahul Athalye, Associate Member, PNNL, Richland, WA*

This session focuses on the application of CFD simulation for air flow and ventilaton performance assessments; and visulization tools and techniques. The first application docuses on CFD simulations of air flow through a reverberant chamber used for HVAC equipment testing which is done to evaluate the effectiveness of different inlet louver configurations. Second, case study of CFD application to assess the natural ventilation performance in an atrium is presented demonstrating the using interactive CFD simulation tools. Another case study demonstrates visualization of CFD results using virtual reality (VR) to provide design feedback for natural ventilation performance simulation.

**1. CFD Simulation of Airflow through World's Largest Reverberant Chamber...N/A**

*Chaitanya Johar, Associate Member, AAON, Inc, Tulsa, OK*

**2. Integration of CFD Simulations in Computational Design for Harnessing the Natural Ventilation Performance of Typical Atrium Spaces in Athens, Greece (C046)...331**

*Angelos Chronis<sup>1</sup>, Foteini Stefopoulou<sup>2</sup> and Katherine Liapi<sup>2</sup>, (1)1: Institute of Advanced Architecture of Catalonia, Barcelona, Spain, (2)University of Patras, Patras, Greece*

**3. An Interactive Visualization Tool for Large-Scale Building Stock Modeling (C047)...338**

*Eric Wilson and Noel Merket, National Renewable Energy Laboratory, Golden, CO*

**4. Visualization of CFD Simulation Results in VR Environment for Design Feedback (C048)...346**

*Charles Steven Sanchez and Xiaoqin Zhang, Energy Research Institute, Nanyang Technological University, Singapore*

3:30 PM - 5:00 PM

**Hybrid Session 16 (Intermediate)**

**Energy Modeling Standards**

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Erik Kolderup, P.E., Member, Kolderup Consulting, San Francisco, CA*

This session covers three ASHRAE Standards related to building energy modeling and thermal performance. ASHRAE Standard 209, Simulation Aided Design, which is a new process standard that sets minimum requirements for the use of building energy simulation in the design of new buildings. The contents of the standard are presented with case studies for designers to transform their approach to energy modeling, giving better language to define what energy modeling is, the purpose it serves at each phase of the project and what questions it can help answer. The second standard covered in the session is Standard 205 titled Standard Representation of Performance Simulation Data for HVAC&R and Other Facility Equipment, which makes the first attempt to standardize the way performance data is conveyed between HVAC equipment manufacturers and energy modelers. Finally, ASHRAE Standard 55 which sets the thermal comfort standard is critically analyzed to help designers understand the requirements and improve its application.

**1. ASHRAE Standard 209: Introduction, Challenges and How to Make an Impact...N/A**

*Erik Kolderup, P.E., BEMP, Member<sup>1</sup> and Kjell Anderson, AIA<sup>2</sup>, (1)Kolderup Consulting, San Francisco, CA, (2)LMN Architects, Seattle, WA*

**2. Modeling Cycles: Using ASHRAE 209P to Define and Integrate Simulation into our Design Process...N/A**

*James Principe and Jill Kurtz, Page, Houston, TX*

**3. Reading and Writing Standardized HVAC Performance Data: An Early Implementation of ASHRAE Standard 205 (C049)...352**

*Neal Kruis, Ph.D., Member<sup>1</sup> and Charles S. Barnaby, BEMP, Life Member<sup>2</sup>, (1)Big Ladder Software, Denver, CO, (2)Retired, Moultonborough, NH*

**4. How to Improve ASHRAE 55 and Make It More Relevant (C050)...359**

*Andrew Corney, P.E., Member<sup>1</sup> and Vladimir Bajic<sup>2</sup>, (1)Trimble - Sefaira, United Kingdom, (2)Trimble - Sefaira, New York, NY*

## Thursday, September 27

Thursday, September 27, 8:15 AM - 8:45 AM

### Keynote 2 (Intermediate)

## High Performance Buildings and the Internet of Things (IoT)

*Room: Continental AB*

### Vivian Loftness, Carnegie Mellon University, Pittsburgh, PA

Will light switches be obsolete? Will every air diffuser be ours to control? Will our windows talk to us? The Internet of Things is finally making it to our workplaces, and it can dramatically improve air quality, visual quality, thermal comfort and desktop energy management. Integrated practices have a strategic advantage by incorporating the Internet of Things (IoT) to significantly advance indoor environmental quality for human health and productivity as well as for energy savings. This presentation will showcase innovations for enclosure, HVAC, lighting and plug load systems - with advanced controls that surf the environment and bring humans-in-the-loop – key to the enduring quality of buildings.

Thursday, September 27, 9:00 AM - 10:30 AM

### Hybrid Session 17 (Intermediate)

## Daylighting Design Strategies

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Lauren Wallace, The Epstein Group, Atlanta, GA*

What is the best methodology for analyzing daylighting? In this series, we bring you seven different presentations focused on Daylighting and Design, each of which will walk through how multiple methods for determining daylight and how these results have affected design. In tandem with daylighting, these presentation will also address thermal comfort, energy analysis, and thermal analysis of building facades.

**1. The Role of Daylight Analysis in Design Decision-Making...N/A**

*Ramana Koti, BEMP, Member, Lord Aeck Sargent, Atlanta, GA*

**2. A Detailed Methodology for Cloud-Based Daylight Analysis (C051)...367**

*Vladimir Bajic<sup>1</sup>, Kerger Truesdell<sup>1</sup> and Andrew Corney, P.E., Member<sup>2</sup>, (1)Trimble - Sefaira, New York, NY, (2)Sefaira, London, United Kingdom*

**3. Integration of Environmental Simulation to Parametric Design Workflow: Thermal Comfort and Daylight (C052)...374**  
*JeeEun Lee, Student Member<sup>1</sup>, Mingbo Peng<sup>2</sup> and Shin-yi Kwan<sup>3</sup>, (1)Cornell University, Ithaca, NY, (2)Thornton Tomasetti Engineers, (3)Nikken Sekkei Ltd, Japan*

**4. The Holistic Design Process: Integrating Daylight Simulations in Dynamo in Revit...N/A**  
*Maha Shalaby, White Arkitekter, Stockholm, Sweden*

**5. Daylighting and Energy Simulation Workflow in Performance-based Building Simulation Tools (C053)(P)...382**  
*Katherine Anderson and Ladan Ghobad, Ph.D., Associate Member, Glumac, Sacramento, CA*

**6. Integrating CFD Techniques with BEM in Early Design Stage to Optimize Design Solutions (C054)(P)...390**  
*Sedighehsadat Mirianhosseinabadi, Ph.D.<sup>1</sup>, Mohit Mehta, Associate Member<sup>2</sup> and Jamy Bacchus<sup>3</sup>, (1)ME Engineers, Golden, CO, (2)M-E Engineers, Inc., Denver, CO, (3)ME Engineers*

**7. An Experimental and Numerical Model of a Solar Facade Prototype with Transparent Insulation and Selective Absorber (C055)(P)...398**  
*Miroslav Cekon, Ph.D.<sup>1</sup>, Richard Slavik<sup>2</sup>, Tomas Fecer<sup>2</sup>, Josef Plasek<sup>2</sup> and Peter Juras<sup>3</sup>, (1)Brno University of Technology, Brno, Czech Republic, (2)Brno University of Technology, Czech Republic, (3)University of Zilina, Slovakia*

9:00 AM - 10:30 AM

### Hybrid Session 18 (Intermediate)

#### Best Practice: HVAC Modeling

*Track: Best Practice*

*Room: Continental AB*

*Chair: Bing Liu, P.E., Member, Northwest Energy Efficiency Alliance, Portland, OR*

Modeling applications for data center cooling, air handling units, air and radiant systems and resiliency for a cogeneration system are presented in this session.

**1. Boosting Confidence in Green-Field Data Center Cooling Performance Using Advanced Simulation Tools and Techniques...N/A**

*Peter Czerwinski, P.E., Member, Jacobs, Pittsburgh, PA*

**3. Model-Based Coupling of Air and Hydronic Systems Operation in a Typical Classroom of a High-Performance Academic Building (C057)...406**

*Arman Mottaghi<sup>1</sup> and Rodrigo Mora, Ph.D., Associate Member<sup>2</sup>, (1)British Columbia Institute of Technology, Canada, (2)British Columbia Institute of Technology, Burnaby, BC, Canada*

**4. Building Integrated Cogeneration System Sizing and Analysis for Climate Disruption (C058)...414**

*Thomas Zakrzewski, Ph.D., BEMP, Associate Member<sup>1</sup> and Brent Stephens, Associate Member<sup>2</sup>, (1)HKS, Inc., Chicago, IL, (2)Illinois Institute of Technology, Chicago, IL*

9:00 AM - 10:30 AM

### Hybrid Session 19 (Advanced)

#### Advanced Modeling: Calibration

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Carrie Brown, Ph.D., Member, Resource Refocus, LLC, Oakland, CA*

Traditional calibration and verification can be repetitive, time consuming, and error prone. This session will cover best practices and common pitfalls for emerging techniques to reduce uncertainty, improve accuracy, identify retrofit opportunities, and reduce consumption with an emphasis on auto-calibration, interoperability, and the use of measured data.

**1. Advances in Calibration of Building Energy Models to Time Series Data (C059)...422**

*David Goldwasser<sup>1</sup>, Brian Hall<sup>1</sup>, Piljae Im, Ph.D., Member<sup>2</sup>, Amanda Farthing<sup>1</sup> and Stephen Frank<sup>1</sup>, (1)NREL, (2)Oak Ridge National Laboratory, Oak Ridge, TN*

**2. Reducing Building Energy Modeling Workloads Through Automated Calibration...N/A**

*Daniel Villa, P.E., Member, Sandia National Laboratories, Albuquerque, NM*

**3. Empirical Validation Under Experiment and Model Uncertainties: Methods and Results...430**

*Qi Li, Ph.D., Argonne National Laboratory, Argonne, IL*

**4. Smart Thermostat Data-Based Residential Buildings Remote Energy Assessments: You Are Probably Doing It Wrong!...N/A**

*Amine Lazrak, Fraunhofer CSE, Boston, MA*

**5. Experimental Calibration of a One-Dimensional Model for Simulating the Dynamical Thermal Behaviour of Stratified Lakes (C060)(P)...N/A**

*Freek Van Riet<sup>1</sup>, Ruben De Wolf<sup>2</sup> and Ivan Verhaert<sup>2</sup>, (1)University of Antwerp, Antwerp, Belgium, (2)University of Antwerp, Belgium*

**6. Modelica Models for Data Center Cooling Systems (C061)(P)...438**

*Wangda Zuo, Ph.D., Member<sup>1</sup>, Yangyang Fu<sup>2</sup> and Michael Wetter, Ph.D., Member<sup>3</sup>, (1)University of Colorado Boulder, Department of Civil, Architectural and Environmental Engineering, Boulder, CO, (2)University of Colorado Boulder, Boulder, CO, (3)Lawrence Berkeley Lab, Berkeley, CA*

**7. Real-Time Performance Analysis Using Energyplus Program Integrated with Bcvtb Platform (C062)(P)...446**

*Yeobeom Yoon, BEMP<sup>1</sup>, Sedighehsadat Mirianhosseinabadi, Ph.D.<sup>2</sup>, Suwon Song<sup>3</sup> and Soolyeon Cho, Ph.D., Member<sup>4</sup>, (1)North Carolina State University, (2)ME Engineers, Golden, CO, (3)Korea Institute of Civil Engineering and Building Technology, (4)North Carolina State University, Raleigh, NC*

9:00 AM - 10:30 AM

**Hybrid Session 20 (Advanced)**

**Software: Tools and Techniques II**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Liam Buckley, CEng, Member, IES Ltd., Oakland, CA*

The session topics span the gamut of the industry sector. Less traditional topics include text-mining to examine the state of energy modeling practice and non-utility/non-energy benefits of facility data analytics. Techniques for flexible (easy to update/modify) models are application-centered topics, while advancements in frameworks and component models reach further back to the question of how to model.

**1. Advanced eQuest Techniques to Make your Model Pliable...N/A**

*Ian Robinson, RDK Engineers, An NV5 Company, Denver, CO*

**2. Parametric Analysis Tool for Early Design Phase Study...N/A**

*Shruti Kasarekar, Associate Member, Atelier Ten, San Francisco, CA*

**3. Energy Modeling Practices Landscape through the Lense of Web-Scraping...N/A**

*Yung Nguyen, BEMP, Associate Member, DNV GL, San Diego, CA*

**4. IBPSA Project 1 - BIM/GIS and Modelica Framework for Building and Community Energy System Design and Operation...N/A**

*Michael Wetter, Ph.D., Member, Lawrence Berkeley National Laboratory, Berkeley, CA*

**5. Interoperable Algorithmic Modeling (IAM): Two-Dimensional Finite Element Method Heat Transfer Translation and Analysis...N/A**

*Kyleen Rockwell, BEMP, Member, HKS, Chicago, IL*

9:00 AM - 10:30 AM

**Conference Paper Session 3 (Intermediate)**

**International Contributions: Best Practices and Case Studies**

*Track: Case Studies*

*Room: Salon A-3*

*Chair: Rahman Azari, Member, University of Texas at San Antonio (UTSA), San Antonio, TX*

This session discusses the impact of thermal insulation on primary energy consumption of buildings and its conflicts with EU's low energy and CO2 emission goals. The session also discusses a passive design strategy tool developed in India that can reduce energy demand and help understand regional variations. A study of reducing primary energy consumption in the public school sector of Denmark is examined. An investigation into how shading from neighbouring buildings effect the energy consumption is discussed for a case study in Hong Kong. Double skin facades and external shading devices' role in reducing energy demand is also discussed.

**1. Implications of EPBD Compliant Facade on Primary Cooling Energy Demand in Central Europe: Theory vs. Practice (C063)...454**

*Javed Iqbal<sup>1</sup>, James V. Dirkes II, P.E., BEMP, Member<sup>2</sup> and Reith Andras<sup>1</sup>, (1)Advanced Building and Urban Design, Hungary, (2)The Building Performance Team Inc, Grand Rapids, MI*

**2. Quantifying the Reduction in Cooling Energy Due to Passive Cooling Techniques for Indian Cities (C064)...462**

**Krishnan Gowri, Ph.D., Fellow ASHRAE<sup>1</sup>, Arjun Desai, Student Member<sup>2</sup> and Prasad Vaidya<sup>2</sup>, (1)BIM2BEM Solutions, Bothell, WA, (2)CEPT University, Ahmedabad, India**

**3. Deep Energy Retrofit vs Improving Building Intelligence: Danish Case Study (C065)...470**

**Muhyiddine Jradi, Ph.D.<sup>1</sup>, Christian Veje<sup>2</sup> and Bo Norregaard Jorgensen<sup>2</sup>, (1)University of Southern Denmark, Odense, Denmark, (2)University of Southern Denmark, Denmark**

**4. Technical and Economic Assessment of a Danish Public School Energy Renovation using Dynamic Energy Performance Model (C066)...478**

**Muhyiddine Jradi, Ph.D.<sup>1</sup>, Bo Norregaard Jorgensen<sup>2</sup> and Christian Veje<sup>2</sup>, (1)University of Southern Denmark, Odense, Denmark, (2)University of Southern Denmark, Denmark**

**5. Effects of Shading on the Energy Consumption of High-Rise Office Buildings in Hong Kong (C067)(P)...486**

**Cong YU and Wei Pan, The University of Hong Kong, Hong Kong S.A.R. (China)**

**6. External Shadings Effect on the Operating Energy in Life Cycle Energy Assessment -LCEA- Case Study Residential Building in Tehran (C068)(P)...494**

**Nasim Eslamirad, HBDP<sup>1</sup> and Mohammadjavad Mahdavejad, Ph.D.<sup>2</sup>, (1)International Imam Khomeini University, Iran (Islamic Republic of), (2)Department of Architecture, Tarbiat Modares University, Tehran, Iran (Islamic Republic of)**

**7. Performance Evaluation and Enhancement of Double Skin Facade in China (C069)(P)...502**

**Yichun Huang, Ph.D.<sup>1</sup>, Hao Zhou, Student Member<sup>2</sup> and Chenguang Xiong<sup>3</sup>, (1)EMSI, Shanghai, China, (2)Tianjin University, Tianjin, China, (3)EMSI, China**

Thursday, September 27, 10:45 AM - 12:00 PM

**Team Case Study 2 (Intermediate)**

**Making the Case for Modeling I**

*Track: Best Practice*

*Room: Salon A-4*

*Chair: Andrew Corney, P.E., Member, Sefaira, London, United Kingdom*

Gain a broader understanding of building performance analysis as presenters in different roles at different types of organizations come together to share their unique perspectives. Presenters include sustainability consultants, a research engineer, and software developers. From a non-profit to a large engineering firm, hear about how the analysis, metrics, and goals vary, including energy-related efforts at the intersection of applied field research, the ways in which energy, daylight, and embodied energy can be integrated with other disciplines, and how simulation tools and analytics can best inform design. The session also addresses what Architects are looking for in Building Performance Analysis.

**1. Building Performance Analysis: A Look Through 4 Lenses...N/A**

**Nicole Peterson<sup>1</sup>, Saranya Gunasingh<sup>2</sup>, Supriya Goel<sup>3</sup> and Krishnan Gowri, Ph.D., Fellow ASHRAE<sup>4</sup>, (1)Thornton Tomasetti, Portland, ME, (2)Seventhwave, Chicago, IL, (3)Pacific Northwest National Laboratory, Richland, WA, (4)BIM2BEM Solutions, Bothell, WA**

**2. What Architects Want from Building Performance Analysis...N/A**

**Andrew Corney, P.E., Member<sup>1</sup>, John Nichols<sup>2</sup>, Dan Overbey, AIA<sup>3</sup>, Rachel Bannon-Godfrey<sup>4</sup> and Colin Rohlfing<sup>5</sup>, (1)Sefaira, London, United Kingdom, (2)Moseley Architects, (3)BDMD Architects, (4)Stantec, (5)HDR Architects**

10:45 AM - 12:00 PM

**Hybrid Session 21 (Intermediate)**

**All About the Weather**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Chip Barnaby, Fellow ASHRAE, Retired, Lexington, MA*

Weather data is critical to building performance simulation. Historical weather data is typically used for energy analysis. However, advances in atmospheric climate modeling and future weather data prediction techniques now offer the potential to generate more accurate weather data for new building design. This session consists of four presenters discussing the pros and cons of using climate modeling vs. historical weather data for building performance simulation, methods of creating future weather data, calculating sub-hourly solar radiation data and innovative approaches to identifying representative location for a climate zone.

**1. How Much Should We Trust Computer Simulated Weather Data?...N/A**

**Yu Joe Huang, White Box Technologies, Inc., Moraga, CA**

**2. Future Weather for Building Design and Urban Analysis...N/A**

*Janet Reyna, National Renewable Energy Laboratory, Washington, DC*

### **3. Development of a Method for Selection of Representative City in a Climate Zone (C070)...510**

*Mayank Bhatnagar, Associate Member<sup>1</sup>, Javed Iqbal<sup>2</sup>, Jyotirmay Mathur, Dr.Eng., Member<sup>3</sup> and Vishal Garg, Ph.D., Member<sup>4</sup>, (1)Malaviya National Institute of Technology Jaipur, jaipur, India, (2)Advanced Building and Urban Design, Hungary, (3)Malaviya National Institute of Technology, Jaipur, India, (4)International Institute of Information Technology, Hyderabad, India*

### **4. Methods for Determining Sub-hourly Solar Radiation from Hourly Data (C071)...518**

*Timothy McDowell<sup>1</sup>, Michaël Kummer<sup>2</sup> and Samuel Letellier-Duchesne, Student Member<sup>3</sup>, (1)Thermal Energy System Specialists, LLC, Madison, WI, (2)Polytechnique Montreal, Montreal, QC, Canada, (3)Ecole Polytechnique de Montreal, Montreal, QC, Canada*

10:45 AM - 12:00 PM

## **Hybrid Session 22 (Intermediate)**

### **Best Practice: Calibration**

*Track: Best Practice*

*Room: Continental AB*

*Chair: Carrie Brown, Ph.D., Member, Resource Refocus, LLC, Oakland, CA*

The discrepancy between simulated and monitored energy performances of a building-- the energy performance gap-- is considered as one of the most significant issues associated with the assessment of energy use in the built environment. The 'errors' or 'uncertainties' in any simulated model are either attributed to the behavior of the occupants, personal bias of the modeler, or the input variables representing the operational schedules of a building. This session will discuss emerging methods to auto-calibrate to as-operated conditions for both residential and commercial mixed-use buildings, with examples from the sub-system level all the way to a campus.

#### **1. Existing Calibration Approaches for Building Performance Comparison and Case Studies...N/A**

*An-Lei Huang, Member, Integral Group, Oakland, CA*

#### **2. Energy Model Calibration for Campus Office Buildings (C072)...526**

*Bo Lin, Ph.D., BEMP<sup>1</sup> and Zhao Chen<sup>2</sup>, (1)Smithgroup, DC, (2)The Pennsylvania State University*

#### **3. Energy Modeling and Calibration of a Mixed-use Building with Laboratories, Offices and Classrooms (C073)...534**

*Liu Liu, Member<sup>1</sup>, Zhengwen Hao<sup>2</sup>, Fuxin Niu, Student Member<sup>2</sup> and Zheng O'Neill, Ph.D., P.E., Member<sup>1</sup>, (1)University of Alabama, Tuscaloosa, AL, (2)The University of Alabama*

#### **4. Calibration of a Building Energy Performance Simulation Model via Monitoring Data (C074)(P)...542**

*Basak Gucyeter, Eskisehir Osmangazi University, Turkey*

#### **5. Energy Modeling of Multi-Storied Residential Buildings: A Manual Calibration Approach (C075)(P)...550**

*Shailza Shailza, Indian Institute of Technology Roorkee, India*

#### **6. Building Energy Model Calibration: A Case Study Using Computational Fluid Dynamics with Air Leakage Testing and On-site Weather Data (C076)(P)...558**

*Tat Fu, Ph.D., P.E., BEMP<sup>1</sup> and Edward Lyon<sup>2</sup>, (1)Simpson Gumpertz & Heger, Waltham, MA, (2)Simpson Gumpertz & Heger*

10:45 AM - 12:00 PM

## **Hybrid Session 23 (Intermediate)**

### **What Is in a Building Type?**

*Track: Case Studies*

*Room: Salon A-3*

*Chair: Vivian Loftness, Carnegie Mellon University, Pittsburgh, PA*

Methodologies for modeling critical facilities, natatoriums, auto service and repair shops, residential buildings, food service buildings and an office building are presented.

#### **1. Statistical Framework for Energy Prediction in Office Buildings...N/A**

*Thulasi Ram Khamma, Student Member<sup>1</sup>, Yuming Zhang<sup>2</sup>, Stephane Guerrier, Ph.D.<sup>2</sup> and Mohamed Boubekri, Ph.D.<sup>3</sup>, (1)University of Illinois at Urbana-Champaign, Champaign, IL, (2)Pennsylvania State University, State College, PA, (3)School of Architecture, University of Illinois at Urbana-Champaign, Champaign, IL*

#### **2. Asset Rating Methodology and Analysis of Food Service Buildings...N/A**

*Juan Gonzalez, PNNL, Arlington, VA*

#### **3. Modeling Indoor Swimming Pools...N/A**

*Suyash Vidwans, Integrated Environmental Solutions Ltd., Atlanta, GA*



**4. A Quicker Method for Determining the UA Value of a Residential Building (C077)(P)...565**

*Tony Chen, Ph.D., James Madison University, Harrisonburg, VA*

**5. Development of a Baseline Building Model of Auto Service and Repair Shop (C078)(P)...573**

*Wangda Zuo, Ph.D., Member<sup>1</sup>, Yunyang Ye<sup>1</sup>, Gang Wang, P.E., Member<sup>2</sup>, Peilin Yang<sup>1</sup> and Joshi Keya<sup>1</sup>, (1)University of Colorado Boulder, Boulder, CO, (2)University of Miami, Coral Gables, FL*

**6. Modeling Critical Facilities for LEED: Lessons Learned (C079)(P)...581**

*Xun Jia, Ph.D., P.E., HBDP, Affiliate and Kris Baker, P.E., Syska Hennessy Group, New York, NY*

10:45 AM - 12:00 PM

**Hybrid Session 24 (Advanced)**

**Advanced Modeling: Energy Storage**

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Vinit Rajesh Gala, University of Illinois, Chicago, IL*

The current trend in electricity tariffs are moving away from simple energy metering and towards peak demand, capacity, and time-of-use pricing. This session discusses the energy storage value proposition and techniques for modeling cost savings for evaluating this new technology. The utilization of batteries in an all-electric multifamily building is presented for peak load shifting during both summer and winter months by operating the batteries as one system in the winter months and multiple systems in the summer months. Another study compares alternative approaches on optimizing grid-connected renewable generation and storage capacity based on carbon instead of cost to mitigate climate change goals. This session also addresses the possibility of utilizing indoor swimming pools available in the cities as a night heat storage system for domestic hot water network for demand reduction, load shifting and reducing operational costs.

**1. Behind-the-Meter Energy Storage: Modeling and Value Stacking...N/A**

*Ian Robinson, RDK Engineers, An NV5 Company, Denver, CO*

**2. Batteries for Peak Shifting in an All-Electric Multifamily Building...N/A**

*Anna McCullough, P.E., Associate Member, Group14 Engineering, PBC, Denver, CO*

**3. Investigating Renewable Energy Generation and Storage Sizing Strategies for All-electric Buildings (C080)...588**

*Rushil Desai<sup>1</sup>, Shivani Shah, Member<sup>2</sup> and Shreshth Nagpal, HBDP and BEMP, Member<sup>2</sup>, (1)Atelier Ten, (2)Massachusetts Institute of Technology, Cambridge, MA*

**4. District Heating Peak Load Reduction by Utilizing Indoor Swimming Pool as a Thermal Storage in New-Town Area (C081)...594**

*Ok Kim<sup>1</sup>, Michael Dahl Knudsen<sup>2</sup> and Steffen Petersen<sup>2</sup>, (1)Aarhus University, Aarhus, Denmark, (2)Aarhus University, Denmark*

Thursday, September 27, 1:30 PM - 5:00 PM

**LowDown ShowDown (Advanced)**

**2018 LowDown Showdown**

*Room: Continental AB*

*Chair: Annie Marston, Ph.D., Ebert and Baumann Consulting Engineers Inc., Washington, DC*

The focus of the 2018 Building Performance Analysis Conference and SimBuild is the adoption of new techniques and workflows to advance modeling and simulation to meet the growing challenges faced by today's designers and modelers. In that spirit, the 2018 LowDown Showdown challenges teams to go beyond just achieving an energy efficient building, and use their ingenuity to include elements of conference themes into their design and analysis.

## Friday, September 28

Friday, September 28, 8:10 AM - 9:00 AM

### Keynote 3 (Intermediate)

#### Modeling Spectrally Selective Fenestration for Indoor Environmental Quality

Room: Continental AB

**Brandon Andow, Front Inc., Brooklyn, NY**

Buildings are increasingly designed with large areas of integrated plantings as a key environmental component whether for biophilia, indoor air quality, building integrated agriculture, or to meet the new health and wellness standards requirements. Fenestration which supports the mixed occupancy of people and plants has potentially conflicting challenges with respect to the spectral transmission of daylight. Spectrally selective glass coatings require co-optimization of transmitted radiation which impacts the rate of photosynthesis, solar heat gain, electric lighting and cooling energy use, visual comfort, and supplemental grow lighting energy use. PAR workflows from recent projects are detailed including The Amazon Spheres, Tianjin Juilliard School, and Longwood Conservatory.

Friday, September 28, 9:10 AM - 10:10 AM

### Team Case Study 3

#### Metrics and Methods: Sustainability

Track: Codes and Standards, Design Strategies

Room: Salon A-4

Chair: Vikram Sami, OLSON KUNDIG, Seattle, WA

This session discusses how architectural design decisions can be critical in achieving low carbon outcomes in buildings. The importance of an integrated design approach involving all stakeholders like planners, architects, engineers and sustainability consultants to think and work to achieve a common goal is discussed. The session throws light on how BIM modelling influences the work flow by handling a bandwidth of design processes ranging from the city level to a façade level and how it can in-turn help increase energy consumption efficiencies.

**1. Data Drivers: How Information Powers Performance Based Design...N/A**

Sean Quinn, AIA, Member, HOK, San Francisco, CA

**2. Redefining Metrics and Methods for a Low Carbon Future...N/A**

Eddy Santosa, BEMP, Member, DBR Engineering Consultants, Inc., Houston, TX

9:10 AM - 10:10 AM

### Team Case Study 4 (Basic)

#### Case Studies: Net-Zero Design Modeling

Track: Case Studies

Room: Salon A-3

Chair: Saranya Gunasingh, Seventhwave, Chicago, IL

The success story of a collaborative approach between the architect and engineer is presented in this session to achieve a Net Zero Energy Hospital. Some innovative strategies like onsite power generation with combined heat and power designs powering absorption machines using waste heat is highlighted here. The session will also showcase different modelling strategies that were adopted to predict the actual energy consumption. Challenges that were overcome to achieve Net Zero Energy status of the Brock Environmental Centre are examined.

**1. It's How You Get There: One Team's Journey to Achieving Net Zero Energy...N/A**

Cindy Cogil, P.E., Member<sup>1</sup> and Oliver Baumann, CPMP, Member<sup>2</sup>, (1)SmithGroup, Chicago, IL, (2)Baumann Consulting, Inc., Washington, DC

**2. Net Zero Energy Hospital Design via Simulation: An Architect and Engineer's Perspective...N/A**

Amir Rezaei-Bazkiaei, Ph.D., Associate Member, CannonDesign, Amherst, NY

9:10 AM - 10:10 AM  
Hybrid Session 25 (Basic)

## Making the Case for Modeling II

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: M. Knight, P.E., Fellow ASHRAE, Whole Building Systems, LLC, Charleston, SC*

In this session learn from the DLR Group about the tactics they used to require including a Performance Designer on every one of their project teams and how to make clients accustomed to the need for this role. Also hear about the successes and failures of different visual elements used by energy modelers to communicate data to decision makers and examples of data visualization including informational graphics and story boarding. And get a demonstration of a web-based energy calculator that can run parametric analysis to determine the cost-effectiveness of the central plant options.

### 1. Performance Designer: An Equal Design Voice...N/A

*Amarpreet Sethi, HBDP and BEMP, Associate Member, DLR Group, Seattle, WA*

### 2. Refining Energy Model Data to Develop a Narrative (C082)...600

*Ivan Jose, Caroline Traube, P.E., BEMP, Member and Skander Spies, McKinstry, Seattle, WA*

### 3. Web-Based Energy Calculator for Master-Planning Project...N/A

*Te Qi, BEMP, Atelierten, san francisco, CA*

9:10 AM - 10:10 AM  
Hybrid Session 26 (Intermediate)

## Project StaSIO

*Track: Best Practice*

*Room: Continental AB*

*Chair: Supriya Goel, Pacific Northwest National Laboratory, Richland, WA*

For energy analysts, one of the most difficult challenges is condensing a great deal of data into an intelligible format so architects can understand it. For architects, one of the challenges in working with analysts is not knowing what performance-related questions can be asked and answered. A solution that connects both of these is IBPSA Project StaSIO, a crowd-sourced, public website that connects performance questions with graphics from simulation outputs that succinctly answers the question. IBPSA-USA's Research Committee organized a competition for submissions of graphics and case studies to populate Project StaSIO. Over 50 excellent submissions were received and this session will explain the motivation behind Project StaSIO and showcase some of the winning entries where the submitters would share their best practices through the graphic and case study examples. They would explain how these graphics helped improve the communication between designers, engineers and energy modelers and helped answer the specific design questions the submissions were developed for.

9:10 AM - 10:10 AM  
Hybrid Session 27 (Advanced)

## Advanced Modeling: Heatpumps

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Tanushree Charan, Georgia Institute of Technology, Atlanta, GA*

This session includes several innovative approaches of modeling and evaluating performance of different heat pump system configurations and control strategies. The first presentation discusses the development of an optimal control strategy for ten parallel heat pumps in an existing building saving about 17.4% energy compared to the original control logic based on the cold water return temperature in the main pipe. Two other presentations discuss the design and operational performance of geo-thermal heat pump systems with case studies including energy modeling and feasibility analysis. Another study explores different configurations of indirect solar assisted heat pump systems with building-integrated combined photovoltaic thermal solar collectors (BiPVT) as an attempt to improve the thermal performance of BiPVT in cold climates. This session also includes a comparison of heating energy consumption of the air-to-air heat pump and air-to-water heat pump system using Energy Plus models. The final presentation is a case study discussing the design level simulations for a Horizontal Earth Tube System (HETS) at the Aldo Leopold Foundation (ALF), Baraboo, WI.

### 1. Optimal Control of Ten Parallel Heat Pumps Using Gaussian Process Model...N/A

*Cheol-Soo Park, Ph.D., Seoul National University, Seoul, Korea, Republic of (South)*

**2. Water Source Geothermal Heat Pump with Horizontal Ground Buried Pipes: Modelling and Optimization with TRNSYS (C083)...607**

*Gaoyang Hou<sup>1</sup> and Hessam Taherian, Ph.D., Member<sup>2</sup>, (1)University of Alabama at Birmingham, (2)University of Alabama at Birmingham, Birmingham, AL*

**3. Investigation and Evaluation of a Horizontally Bored Geothermal Heat Pump System Used in the Cold Climate of the U.S (C084)(P)...615**

*Rui Miao, Student Member<sup>1</sup>, Yao Yu, Ph.D., BEMP and BEAP, Associate Member<sup>2</sup> and Rick Audette<sup>3</sup>, (1)North Dakota State University, (2)North Dakota State University, Fargo, ND, (3)Grand Forks Airport International Terminal, Grand Forks, ND*

**4. Performance of Heat Pump Assisted Building-integrated Combined Photovoltaic Thermal Solar Collectors (BiPVT) in Cold Climate (C085)(P)...623**

*Khem Raj Gautam and Gorm Bruun Andresen, Aarhus University, Denmark*

**6. An Analysis on the Thermal Performance of a Horizontal Earth Tube System (C086)(P)...631**

*Hoda Barzegar Garji, Student Member, D. Michael Utzinger, P.E., Member and Kevin Renken, University of Wisconsin-Milwaukee, Milwaukee, WI*

Friday, September 28, 10:30 AM - 12:00 PM  
**Hybrid Session 28 (Intermediate)**

**Early Design Modeling II**

*Track: Best Practice*

*Room: Continental AB*

*Chair: Erik Kolderup, P.E., Member, Kolderup Consulting, San Francisco, CA*

The second of two sessions on early design presents both applied and theoretical topics. A case study on the design of outdoor learning space is presented, pairing well with a practitioner perspective on outdoor comfort modeling tools. A practitioner perspective on multi-objective optimization (MOO) is provided. The digitalization of models and information is explored, in the form of models easily transported between design stages and tools, and rapid location of technology options via the semantic web. Lastly, the use of the “constructal law” of nature (e.g., branching patterns of a tree) optimizes the layout of spaces and mechanical systems.

**1. Designing for Thermal Nirvana...N/A**

*Shona O Dea, BEMP, Associate Member, BEMP, LEED AP, WELL AP, CPHC, Chicago, IL*

**2. Integrating Simulation Tools with Learnings from Nature: A Methodology for Form Generation by Emulating the Constructal Law of Nature(C087)...639**

*Mehdi Azizkhani, Ph.D., Member and Juan-Carlos Baltazar, Ph.D., P.E., BEMP, Member, Texas A&M University, College Station, TX*

**3. Assessing the Multi Objective Optimization Methodology for Performance-Based Building Design in Professional Practice (C088)...646**

*Xiaofei Shen<sup>1</sup>, Aman Singhvi<sup>1</sup>, Andrea Mengual<sup>1</sup>, Maria Spastr<sup>2</sup> and Victoria Watson<sup>2</sup>, (1)AECOM, New York, NY, (2)AECOM, Orange, CA*

**4. Using Digitalization for More Reliable and Less Expensive Building Performance Analysis (C089)...654**

*Christoph Maurer, Dr.Ing.<sup>1</sup>, Helen Rose Wilson<sup>2</sup>, Dragan Curcija<sup>3</sup> and Tilmann Kuhn<sup>2</sup>, (1)Fraunhofer Institute for Solar Energy Systems ISE, Department Energy Efficient Buildings, Freiburg, Germany, (2)Fraunhofer Institute for Solar Energy Systems ISE, Department Energy Efficient Buildings, Germany, (3)Lawrence Berkeley National Laboratory, Berkeley, CA*

**5. From Architectural 3D Models to Outdoor Comfort Prediction: A Review of Simulation Tools from a Designer Perspective (C090)...659**

*Emanuele Naboni<sup>1</sup>, Silvia Cocco<sup>2</sup>, Marco Meloni<sup>1</sup> and Jean-Louis Scartezini<sup>2</sup>, (1)The Royal Danish Academy, Denmark, (2)EPFL, Switzerland*

10:30 AM - 12:00 PM  
**Hybrid Session 29 (Advanced)**

**Data Science and Machine Learning Applications**

*Track: Tools and Techniques*

*Room: Salon A-1*

*Chair: Ralph Muehleisen, Ph.D., P.E., Member, Argonne National Laboratory, Lemont, IL*

Machine learning techniques have great potential for analyzing, synthesizing and extracting value from building performance data. This session introduces the concept and application of deep reinforcement learning, batch reinforcement learning and related machine learning approaches for optimal HVAC control and predicting building

energy performance. Data science and statistical simulation approach is shown as a potential solution for rapid analysis of large scale simulation.

**1. Bridging Machine Learning and Controls for Demand Response and Building Energy Management...667**

*Achin Jain, University of Pennsylvania, Philadelphia, PA*

**2. Combined Ontology-Driven and Machine Learning Approach to Monitoring of Building Energy Consumption (C092)...676**

*Parastoo Delgoshaei<sup>1</sup>, Mohammad Heidarinejad, Ph.D., Associate Member<sup>2</sup> and Mark Austin<sup>3</sup>, (1)National Institute of Standards and Technology, Gaithersburg, MD, (2)Illinois Institute of Technology, Chicago, IL, (3)University of Maryland, College Park, MD*

**3. A Deep Reinforcement Learning Approach to Using Whole Building Energy Model for HVAC Optimal Control (C093)...684**

*Zhiang Zhang, Student Member<sup>1</sup>, Adrian Chong<sup>2</sup>, Yuqi Pan, Student Member<sup>3</sup>, Chenlu Zhang<sup>1</sup>, Siliang Lu, Student Member<sup>4</sup> and Khee Poh Lam, Ph.D.<sup>1</sup>, (1)Carnegie Mellon University, Pittsburgh, PA, (2)National University of Singapore, Singapore, (3)Ghafari Associates, (4)Center for Building Performance and Diagnostics, School of Architecture, Carnegie Mellon University, Pittsburgh, PA*

**4. Adaptive Multi-Agent Control of HVAC Systems for Residential Demand Response Using Batch Reinforcement Learning (C094)...692**

*Jose Ramon Vázquez-Canteli<sup>1</sup>, Stepan Ulyanin<sup>1</sup>, Jerome Kampf<sup>2</sup> and Zoltan Nagy, Ph.D.<sup>3</sup>, (1)Intelligent Environments Laboratory, Department of Civil, Architectural and Environmental Engineering, The University of Texas, Austin, TX, (2)ENERGY Institute, Haute Ecole d'Ingénierie et d'Architecture de Fribourg, Fribourg, Switzerland, (3)The University of Texas at Austin, Austin, TX*

**5. Analysis of a Large-Scale Database for Energy Performance Modeling of Existing Buildings by Sorting the Energy Consumption Patterns (C095)(P)...700**

*Hye-Gi Kim, Ph.D.<sup>1</sup>, Jea Eun Sung<sup>2</sup> and Sun Sook Kim, Ph.D., Member<sup>3</sup>, (1)Ajou University, Department of Architecture, Suwon, Korea, Republic of (South), (2)Ajou University, Department of Architecture, Korea, Republic of (South), (3)Ajou University, Suwon, Korea, Republic of (South)*

10:30 AM - 12:00 PM

**Hybrid Session 30 (Advanced)**

**Innovative Modeling Techniques**

*Track: Case Studies*

*Room: Salon A-3*

*Chair: Carrie Brown, Ph.D., Member, Resource Refocus, LLC, Oakland, CA*

Attend this session to learn about: an innovative hybrid application of PCM modelled in EnergyPlus and validated with results from a fully-functioning installation in a London school; the development of a reduced-order energy model calibrated by metered utility data under ASHRAE Guideline 14; a bottom-up approach for energy benchmarking utilizing energy usage effectiveness; a new strategy to reduce demand charges that is based on the analysis of all feasible energy consumption and peak reduction measures, for any building type under different usage scenarios; a dynamic simulation model for the envelope and HVAC system of a typical large office building; and a new modeling technique to flow network modeling that can lead to faster simulation times.

**1. EnergyPlus Model of Novel PCM Cooling System Validated with Installed System Data...N/A**

*Chao Yang, Member, BuroHappold Engineering, Los Angeles, CA*

**2. Reduced-order Energy Modeling in Retro-Commissioning: A Case Study of an Academic Building (C098)...716**

*Saber Khoshdel Nikkho<sup>1</sup> and Jeff Steffensen<sup>2</sup>, (1)Affiliated Engineers Inc., Rockville, MD, (2)Affiliated Engineers Inc.*

**3. Influence of Plug and Process Loads and Occupancy on Ultimate Energy Savings: A New Approach (C099)...722**

*Roger Chang, P.E., BEMP, Member<sup>1</sup> and Drury Crawley, Ph.D., BEMP, Fellow ASHRAE<sup>2</sup>, (1)DLR Group, Washington, DC, (2)Bentley Systems, Inc., Washington, DC*

**4. Optimal Strategy for Demand Charge Reduction in Commercial Buildings (C100)...730**

*Yuna Zhang, Ph.D., Student Member<sup>1</sup> and Godfried Augenbroe<sup>2</sup>, (1)Baumann Consulting Inc., Washington, DC, (2)Georgia Institute of Technology, Atlanta, GA*

**5. A Control-Oriented Building Envelope and HVAC System Simulation Model for a Typical Large Office Building (C101)(P)...738**

*Sen Huang<sup>1</sup>, Yan Chen<sup>1</sup>, Paul Ehrlich, P.E.<sup>1</sup> and Draguna Vrabie<sup>2</sup>, (1)Pacific Northwest National Laboratory, (2)United Technology Research Center, East Hartford, CT*

**6. A Pseudo-Transient Method for Modeling Flow Networks (C102)(P)...746**

*Christopher Aaron Powers, Johnson Controls, Inc.*

10:30 AM - 12:00 PM  
Hybrid Session 31 (Intermediate)

## Beyond Energy

*Track: Codes and Standards, Design Strategies*

*Room: Salon A-4*

*Chair: Susan Collins, Whole Building Systems, Charleston, SC*

This session covers diverse topics, including the current challenges in defining plumbing fixture usage and rain fall patterns, change-of-season heating demand increment as amplified by the human thermal adaptation lag, indoor air tracing and alternative-strategy dehumidification models.

### 1. Challenges and Opportunities in Whole Building Water Modeling (C103)...752

*Fred Betz and Lyle Keck, Affiliated Engineers, Inc., Madison, WI*

### 2. Simulation-Driven Design: Integration of Energy Simulation and Daylighting to Inform High-rise Buildings...N/A

*Elnaz Tafrihi, Student Member<sup>1</sup> and Edmund Rivera<sup>2</sup>, (1)UC Berkeley, Berkeley, CA, (2)Steinberg Hart, San Jose, CA*

### 3. Unpacking Mid-Season Heating Demand in Social Housing (C104)...760

*Victoria Aragon, Julian David Quintero, Stephanie Gauthier, Patrick James and Abubakr Bahaj, University of Southampton, Faculty of Engineering and the Environment, United Kingdom*

### 4. Pulse Air Tracing...N/A

*Clifford Cooper, Member, ASHRAE MTG.ACR; Personalized Environmental Control System (PECS) working group (WG) within the Ventilation Sub-committee of SSPC62.1, Kingston, NY*

### 5. Dehumidification Strategies and Their Applicability (C105)(P)...768

*Jagan Pillai, P.E., BEMP, Associate Member<sup>1</sup> and Rushil Desai<sup>2</sup>, (1)Atelier Ten, New York, NY, (2)Atelier Ten*

### 6. Heat and Mass Transfer Analysis of the Micro-porous Membrane/Phase Change Material Based Energy Recovery Ventilator (C106)(P)...776

*Mohammed Salman Mohiuddin, Student Member and Weihuan Zhao, Ph.D., University of North Texas, Denton, TX*

10:30 AM - 12:00 PM  
Conference Paper Session 4 (Advanced)

## Advanced Modeling: Controls

*Track: Advanced Modeling*

*Room: Salon A-5*

*Chair: Annie Marston, Ph.D., Hurley Palmer Flatt, London, United Kingdom*

Papers address: workflows in which building designers configure control sequences, an integrated solution for incorporating digital twins of real buildings into existing SCADA systems, a study on operational considerations of joint optimization of millions of load set point adjustments, an investigation of the influence of weather data on low-voltage grid impact indicators calculated within a previously developed probabilistic framework, an occupant detection system that uses the Blue Tooth signal to infer occupant presence, a testing facility to monitor typical building controls points to characterize thermal response models with outdoor and indoor conditions, and a case study on a model-based approach to fault impact analysis, which can be used for analyzing the impact of single or multiple faults.

### 1. OpenBuildingControl: Modeling Feedback Control as a Step Towards Formal Design, Specification, Deployment and Verification of Building Control Sequences (C107)...784

*Michael Wetter, Ph.D., Member<sup>1</sup>, Jianjun Hu<sup>1</sup>, Milica Grahovac<sup>1</sup>, Brent Eubanks, P.E., Member<sup>2</sup> and Philip Haves<sup>1</sup>, (1)Lawrence Berkeley National Laboratory, Berkeley, CA, (2)Integral Group, Oakland, CA*

### 2. Digital Twins for Efficient Modeling and Control of Buildings: An Integrated Solution with SCADA Systems (C110)...808

*Derek Nong<sup>1</sup>, Achin Jain<sup>2</sup>, Truong Nghiem, Dr. Ing.<sup>2</sup> and Rahul Magharam<sup>2</sup>, (1)University of Pennsylvania, (2)University of Pennsylvania, Philadelphia, PA*

### 3. Characterizing Electric Grid System Benefits of MPC-based Load Shaping (C109)...800

*Robert F. Cruickshank III, Student Member<sup>1</sup>, Anthony Florita<sup>1</sup>, Gregor Henze, Ph.D., P.E., Member<sup>3</sup> and Charles Corbin, Ph.D.<sup>4</sup>, (1) National Renewable Energy Laboratory, Golden, CO, (3) University of Colorado, Boulder, CO, (4)Pacific Northwest National Laboratory, Richland, PA*

### 4. Sensitivity of Low-voltage Grid Impact Indicators to Weather Data in Residential District Energy Modeling (C108)...792

*Dirk Saelens<sup>1</sup> and Christina Protopapadaki<sup>2</sup>, (1)EnergyVille, Belgium, (2)KU Leuven, Department of Civil Engineering, Building Physics Section, Heverlee, Belgium*

### 5. A Bluetooth Based Occupancy Detection for Buildings (C111) (P)...816

*Thomas Ryun Dougherty, Student Member<sup>1</sup>, Zoltan Nagy, Ph.D.<sup>2</sup> and June Young Park<sup>2</sup>, (1)The University of Texas at Austin, Intelligent Environments Laboratory, Austin, TX, (2)The University of Texas at Austin, Austin, TX*

**6. A Methodology to Infer Thermal Response of Building Components to Support Model Predictive Control (C112)(P)...824**  
*Elizabeth LeRiche and JJ McArthur, Ryerson University, Canada*

**7. A Simulation Based Approach to Impact Assessment of Physical Faults: Large Commercial Building HVAC Case Study (C113)(P)...832**

*Yan Chen<sup>1</sup>, Sen Huang<sup>1</sup> and Draguna Vrabie<sup>2</sup>, (1)Pacific Northwest National Laboratory, (2)United Technology Research Center, East Hartford, CT*

### **Additional Paper:**

**An Open Science Approach for Building Performance Studies...708**

Steven K Firth, Gareth Cole, Tom Kane, Farid Fouchal, Tarek M Hassan