

2022 Building Performance Analysis Conference and SimBuild

September 14th - September 16th, 2022



Wednesday, September 14

Wednesday, September 14, 8:10 AM - 9:00 AM

Keynote

Donnel Baird

Donnel Baird is the founder of BlocPower, a climate tech startup based in Brooklyn. BlocPower's tech platform analyzes, finances, and installs clean energy and building decarbonization upgrades in buildings in underserved communities. BlocPower creates jobs for qualified local low-income workers, energy savings for building owners, reduces carbon emissions and asthma rates, and provides financial returns to investors. In 2021, the company announced a historic partnership with Ithaca, New York to decarbonize 100% of the city's buildings—the first such project in the United States. Baird is a graduate of Duke University and Columbia Business School.

Wednesday, September 14, 9:10 AM - 10:10 AM
Paper Session 1 (Intermediate)

Daylighting

Room: Monroe Room

Chair: Nicole Peterson, Thornton Tomasetti, Portland, ME

This session introduces recent advances in daylighting analysis and design technologies. First, we consider a novel computational workflow to customize illuminance ranges and select target areas to examine local light levels in residential applications. Then, we explore the ability of vectorized computer languages to increase the speed of annual daylighting calculations. Finally, we show how parametric iterative algorithms can be used to design prismatic skylights that optimize useful daylight, glare reduction, and energy consumption.

1. Speeding up Annual Daylighting Simulation Using NumPy

Nathaniel L Jones, Ph.D., Associate Member, Arup, Boston, MA

2. Energy and Daylight Simulation Analysis of an Innovative Horizontal Skylight System Incorporating a Bi-directional Scattering Distribution Function (BSDF) Prismatic Optical Layer

Mohammad Salamat¹, Wayne Place¹, Curtis Fentress² and Masoome Haghani¹, (1)North Carolina State University, Raleigh, NC, (2)Fentress Architects, Denver, CO

3. Using Illuminance Ranges and Target Areas to Analyze Daylight in Multi-Dwelling Units

Guanzhou Ji and Azadeh O. Sawyer, Carnegie Mellon University, Pittsburgh, PA

9:10 AM - 10:10 AM

Seminar 1 (Basic)

An Effective Solution for Climate Change Adaptation, IAQ and Energy Considerations

Room: Chicago Room

Chair: Jo Norris, Member, Carbon Reform, Newark, DE

This session will be an interactive exploration of climate change, carbon removal, energy use, and indoor air quality in the built environment. Through a participatory framework using a software tool to help facilitate conversation, we will simulate a methodology for assessing risks in the built environment, identifying pain points of building owners and occupants, and developing a novel solution for the identified energy, indoor air quality, and climate adaptation challenges. A technical background will be provided at the start of the session and then a series of questions will be asked to guide participants through the simulated product development experience.

1. An Effective Solution for Climate Change Adaptation, IAQ, and Energy Considerations

Jo Norris, Member¹ and Nancy McClellan, MPH, CIH, CHMM, Member², (1) Carbon Reform, Newark, DE, (2) American Industrial Hygiene Association, Falls Church, VA

9:10 AM - 10:10 AM

Seminar 2 (Intermediate)

Modeling Existing Buildings

Room: Water Tower Parlor

Chair: John Bynum, Ph.D., Member, ARUP, Dublin, Ireland

Modelling of existing buildings presents unique challenges which can differ quite substantially from one building to the next depending on many technical and non-technical factors. This session covers two tools for assessing existing buildings as well as one unique case study of a historic museum. The first tool discussed is focused on retrofitting opportunities for small to medium commercial buildings while the second is focused on rapid modelling for ESG assessments. The museum case study presents the use of specialized simulation techniques to solve the specific challenges facing the museum.

1. Frozen Paintings, Interior Gutters: Simulating a 1960s Museum

Graham Linn, P.E., HabLab, Madison, WI

2. A Simple Building Calculator (SBC) for Evaluating Commercial Building Performances

Weili Xu, Ph.D., Associate Member¹, Chitra Nambiar, Associate Member² and Reid Hart, P.E., Life Member³, (1)PNNL, United States of America, Seattle, WA, (2)PNNL, United States of America, (3)PNNL, United States of America, Richland, WA

3. Energy Modeling for Green Property Conditioning Assessment

Krishnan Gowri, Ph.D., BEMP, Fellow ASHRAE, Intertek Building Science Solutions, Bothell, WA

9:10 AM - 10:10 AM
Seminar 3 (Intermediate)

Occupant Health, Well-being and Comfort

Room: Adams Room

Chair: Walter Grondzik, P.E., Fellow Life Member, Ball State University, Muncie, IN

This session presents three studies that use advanced simulation and analysis techniques to assess the impacts of the built environment on human occupants. The first presentation investigates the variation of temperature across time and across space in single family residences and its impact on thermal comfort. This is followed by a study of the impact of thermal conditions on sleep for older occupants. The final presentation considers the impact on occupant behavior patterns of simulated building performance metrics.

1. Validation of Spatiotemporal Thermal Comfort Variation in Single-Family Residential Buildings

Maharshi Pathak, Student Member, Emily Casavant, Student Member, David Fannon and Michael Kane, Ph.D., Member, Northeastern University, United States of America, Boston, MA

2. The Impact of Bedroom Thermal Environment on Sleep in Community-Dwelling Older Adults

Amir Baniassadi, Ph.D.¹, Wanting Yu², Ryan Day², Angel Wong², Thomas Trivison, Ph.D.¹, Lewis Lipsitz, M.D.¹ and Brad Manor, Ph.D.¹, (1)Harvard Medical School, Boston, MA, (2)Marcus Institute for Aging Research, Boston, MA

3. The Potential of Building Simulation Integrated into Behavioral Experiments

JeeEun Lee, Student Member and Ying Hua, Ph.D., Cornell University, Ithaca, NY

Wednesday, September 14, 10:30 AM - 12:00 PM

Paper Session 2 (Intermediate)

Approaches to Modeling Future Weather, Climate and Extreme Events I

Room: Adams Room

Chair: Drury Crawley, Ph.D., Fellow Life Member, Bentley Systems, Inc., Washington, DC

This session discusses the role future weather, climate and other extreme climate events play in decisions concerning the nexus between energy efficiency, resiliency, and load flexibility. The first presentation discusses optimization approaches for building envelope to account for future climatic demands. The next presentation discusses the development of a simplified battery storage sizing tool to estimate storage needs for homes operating off-grid. The session discusses the importance of a stochastic model of future weather conditions, so that dynamics between resilience metrics and efficiency metrics can be fairly assessed. The final presentation evaluates the passive survivability under extreme weather events.

1. Multi-scenario Extreme Weather Simulator Application to Heat Waves

Villa, Daniel L. Villa¹, Juan Pablo Carvallo, Ph.D.², Carlo Bianchi³ and Sang Hoon Lee, Ph.D.⁴, (1)Sandia National Laboratories, (2)Lawrence Berkeley National Laboratory, Berkeley, CA, (3)National Renewable Energy Laboratory, Golden, CO, (4)Lawrence Berkeley National Laboratory, United States of America

2. Building Envelope Optimization for Future Climatic Demands by Simple-Box Model Energy Simulation

Mitra Azimi and Juan Carlos Baltazar, Texas A&M University, College Station, TX

3. Evaluation of the Thermal Resilience of a Community Hub

Aylin Ozkan, Ph.D.¹ and Joel Good, P.Eng.², (1)RWDI, Toronto, ON, Canada, (2)RWDI, Vancouver, BC, Canada

4. Development of a Battery Capacity Sizing Tool for Optimal Sizing of Residential-Scale Backup and Microgrid Energy Systems

Kate Bren, Maya Hazarika and Charles Upshaw, Positive Energy

10:30 AM - 12:00 PM

Paper Session 3 (Intermediate)

CFD Applications for Architectural Decision Making

Room: Monroe Room

Chair: Wangda Zuo, University of Colorado Boulder, Boulder, CO

This session introduces some of the recent CFD applications, ranging from thermal comfort, health, to emergency management. First, speakers evaluate the thermal performance and thermal comfort provided by newly design thermally active student's desk. Speakers also discuss the health-related applications, including using CFD to assess the COVID spread in a grocery store as well as discuss how to combine CFD with machine learning to accelerate the simulation of particulate modeling around buildings. Lastly, speakers explain how to use CFD to assist the safe evacuation analysis and means of egress layout for emergencies.

1. Numerical Investigation of Thermal Comfort of Thermally Active Students Desk (TASD) in a Historical Building

Lobna Mitkees¹, Mohammad Heidarinejad, Ph.D., P.E., Associate Member¹ and Brent Stephens, Associate Member², (1)Illinois Institute of Technology, Chicago, IL, (2)Illinois Institute of Technology, Chicago, IL, USA

2. A Computational Fluid Dynamics Model for the Assessment of Sars-cov-2 Aerosol Dispersion Inside A Grocery Store
Mingkan Zhang, Ph.D., Member¹, Prateek Shrestha¹, Xiaobing Liu, Ph.D., Member¹, Jason DeGraw, Ph.D., Member¹, Dustin Schafer, P.E.² and Nathan Love², (1) Oak Ridge National Laboratory, Oak Ridge, TN, (2)Henderson Engineers, Lenexa, KS

3. Towards Healthy Built Environments: A Hybrid CFD and Machine Learning Approach for Modeling Airflow and Particulate Matters Around Buildings
Mehdi Ashayeri¹ and Narjes Abbasabadi², (1) Southern Illinois University, Carbondale, IL, (2) University of Texas, Arlington, TX

4. Using CFD Model to Assist Safe Evacuation Analysis and Means of Egress Layout Evaluation in Adaptive Re-use
Chen, Xiaolei Chen, California State University

10:30 AM - 12:00 PM

Seminar 4 (Intermediate)

Modeling Advances: Tools and Workflows I

Room: Water Tower Parlor

Chair: Aaron Boranian, Associate Member, Big Ladder Software, Denver, CO

This session starts with discussing a new tool that assists designers by integrating commercial building energy surveys, recent ASHRAE research, and comparative analysis of historical vs. future weather data. This session also covers the predictability of future occupant presence based on collected occupancy sensor data, as well as the impact of tangential costs (repairing damaged interior finishes as part of a fenestration replacement project, e.g.) on results of Life-Cycle Cost Analysis (LCCA). The session concludes with a discussion of balancing simulation precision and detail with efficiency and profit margins via benchmarking, simplified analysis, and isolated test models.

1. Rapid Energy Design Tool: Research-Grade Energy and Climate Data for Energy-Conscious Design

Amir Rezaei-Bazkiaei, Ph.D., BEMP, Associate Member¹ and Brett Horin², (1)CannonDesign, Buffalo, NY, (2)CannonDesign, Chicago, IL

2. Predictability Analysis of Occupant Presence in Residential Buildings

Sunghyun Kim and Cheol-Soo Park, Ph.D., Department of Architecture and Architectural Engineering, Seoul National University, Seoul, Korea, Republic of (South)

3. Building Enclosure Life-Cycle Cost Analysis: Examples of Bias and the Skewing of Results

Cheryl Saldanha, P.E.¹ and Abigail Sefah², (1)Simpson Gumpertz & Heger, New York, NY, (2)Simpson Gumpertz & Heger, Boston, MA

4. Level of Detail Question in Building Simulations

Emir Pekdemir, BEMP, Associate Member, WSP USA, New York, NY

10:30 AM - 12:00 PM

Seminar 5 (Intermediate)

Open-Source Modeling for District Energy Systems

Room: Chicago Room

Sponsor: 4.7 Energy Calculations

Chair: Wangda Zuo, Ph.D., Member, Pennsylvania State University, State College, PA

This seminar introduces recent efforts in developing open-source modeling tools for district energy systems based on URBANopt and Modelica Buildings library, which is a joint effort of NREL, LBNL and Penn State. We will introduce new Modelica models for steam-based district heating system and future low carbon systems. Then we will discuss the integration of URBANopt and Modelica. We will also demonstrate the usage of such tool with some real-world examples.

1. A Fast and Accurate Modeling Approach for Water and Steam Thermodynamics with Practical Applications in District Heating System Simulation

Wangda Zuo, Ph.D., Member, Pennsylvania State University, State College, PA

2. Design of Decarbonized District Energy Systems with the Modelica Buildings Library

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

3. Rapid Development of District Models Using Urbanopt District Energy System

Nicholas Long, P.E., Member, National Renewable Energy Laboratory, United States of America, Golden, CO

Wednesday, September 14, 1:40 PM - 3:10 PM

Paper Session 4 (Intermediate)

Innovations in Passive and Hybrid Heating and Cooling I

Room: Adams Room

Authors in this session discuss several strategies evaluated for the City of Chicago to reduce residential heating loads, natural ventilation as a passive technology and shows two data-driven advanced control designs for natural ventilation, integrating algae photobioreactors into facades, to act as a passive HVAC system, and recover the heat generated by the system for space heating. Also presented are façade-integrated photovoltaics and an evaluation of different configurations which can impact the efficiency of the system as well as an innovative wall component integrating the flexible PV panels with the wall insulation system.

1. Sun and Stone in the Windy City: New Evidence for Direct Solar Heating Performance in Greater Chicago

Alexandra R. Rempel, Ph.D. and Alan Rempel, University of Oregon, Eugene, OR

2. Performance of Energy Activated ETICS Applied in the Urban Environment of Street Canyons

Dominika Knera, Dariusz Heim and Anna Wieprzkowicz, Lodz University of Technology, Poland

3. Direct Integration of Flexible Photovoltaic with the Wall: A Simulation Approach to Determine Panel Performance

Dariusz Heim, Anna Wieprzkowicz and Dominika Knera, Lodz University of Technology, Poland

4. Simulation-based Control of Natural Ventilation with Operable Windows: Transformation from Predictive Control into Reinforcement Learning Control

Wei Zhang and Ali Malkawi, Harvard Center for Green Buildings and Cities, Cambridge, MA

1:40 PM - 3:10 PM

Paper Session 5 (Intermediate)

Modeling Advances and Validation of Modeling Results

Room: Monroe Room

Chair: Jeannie Kim, Argonne National Laboratory, Lemont, IL

This session covers various topics related to large-scale residential building analysis and validation of modeling results using empirical data. The first speaker covers a large-scale simulation methodology which evaluated the impact of trade-offs on building envelope performance. The second presentation introduces a methodology for using empirical data for residential buildings to validate predicated energy use results. Next, a random forest machine learning model to predict envelope assembly characteristics for existing buildings is presented. The final presentation evaluates the effects of a new daylighting system on the thermal and electric load of a typical office building.

1. Energy Performance Comparison of Venetian Blind and a New Daylighting System: Combined System of Reversible, Energy Conservative Window-Shading

Masoome Haghani¹, Behrouz Mohammad Kari² and Rima Fayaz³, (1)NCSU, (2)Building and Housing Research Center (BHRC), Tehran, Iran, (3)Department of Architecture, Art University of Tehran, Iran

2. Predicting Building Envelope Construction from In-Situ Thermal Testing

Tyler James Pilet¹ and Tarek Rakha², (1)Pacific Northwest National Laboratory, (2)Georgia Institute of Technology, Atlanta, GA

3. Large Scale Simulation to Investigate the Residential Envelope Trade-offs for High-Efficiency Equipment and Renewables Based on 2021 IECC

Yulong Xie, Ph.D.¹, Victor Salcido¹, Yan Chen, Ph.D.², Todd Taylor², Benjamin Taube² and Michael Rosenberg, Fellow ASHRAE², (1)Pacific Northwest National Laboratory, Richland, WA, (2)Pacific Northwest National Laboratory, Portland, OR

4. Coupled Model of Heat and Power Flow in Unventilated PV/PCM Wall-Initial Validation of the En-ActivETICS

Anna Wieprzkowicz, Dominika Knera and Dariusz Heim, Lodz University of Technology, Poland

5. Improving Residential Building Simulations Through Large-Scale Empirical Validation

Benjamin Park, Scott Horowitz, Noel Merket and Dave Roberts, NREL

1:40 PM - 3:10 PM

Seminar 6 (Intermediate)

Intelligent Building Operations: Efficiencies and Load Management I

Room: Water Tower Parlor

Chair: Alexandra R. Rempel, Ph.D., University of Oregon, Eugene, OR

How can we best choreograph the many moving parts of building systems for greatest efficiency or effectiveness? This session explores new integrations of coordinated space heating systems, the optimization of fire prevention systems, and the development and application of an extensive new end use load profile database.

1. Integrated Control of Radiant Floor Heating Systems in Residential Buildings

Seongkwon Cho¹, Jin-Hong Kim¹ and Cheol-Soo Park, Ph.D.², (1)Seoul National University, Seoul, Korea, Republic of (South), (2)Department of Architecture and Architectural Engineering, Seoul National University, Seoul, Korea, Republic of (South)

2. End Use Load Profiles

Eric Wilson, Andrew Parker, Anthony Fontanini and Matthew Dahlhausen, Ph.D., Associate Member, National Renewable Energy Laboratory, Golden, CO

3. COVID-19 Impacts on Residential Energy Usage from the Northwest End Use Load Research Project

Jessica N. Keast, Resource Refocus, Berkeley, CA

4. Bayesian Network-Based Probabilistic Approach for Optimal Placement of Fire Detectors for Fire Safety Performance-Based Design

Jung Ah Lee and Sean Hay Kim, Ph.D., Seoul National University of Science and Technology, Seoul Metropolitan City, Korea, Republic of (South)

1:40 PM - 3:10 PM

Seminar 7 (Advanced)

Optimizing Buildings for Zero Carbon Lifetime Operations: Part 2

Room: Chicago Room

Chair: Jamy Bacchus, P.E., Member, ME Engineers, Denver, CO

This session is a follow-up to our 2021 ASHRAE BPAC session: 30-yr GHG Forecasts Using Marginal and Average Emissions, where we sought to optimize office building design for minimal operational carbon by employing strategies including electrification, onsite renewables, and battery storage. This session will focus on analyzing multifamily buildings' lifetime emissions using NREL's hourly Cambium data and design optimization using the same intervention strategies. We will discuss updates to the Cambium data, which now includes upstream methane, and the impact on the previous results. We will also analyze the mechanical systems' refrigerants and their Scope 1 emissions.

1. Optimizing Office Buildings for Zero Carbon Lifetime Operations (a review)

Jamy Bacchus, P.E., BEMP, Member, ME Engineers, Denver, CO

2. Optimizing Multifamily Buildings for Zero Carbon Lifetime Operations

Caitlin Anderson, P.E., Member, ME Engineers, Denver, CO

3. Analyzing Refrigerant Scope 1 Emissions for Lifetime Operations

Sedighehsadat Mirianhosseinabadi, Ph.D., Associate Member, ME Engineers, Golden, CO

Wednesday, September 14, 3:30 PM - 5:00 PM

Paper Session 6 (Intermediate)

Urban and Community Scale Modeling

Room: Adams Room

Chair: Andy Berres, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN

Urban scale and building stock simulations present the challenge of representing many buildings through a much smaller number of models. First, authors share how building type can be inferred from utility-provided energy use data. Then, they evaluate how well common data-driven black-box models work for regulatory calculations to support policy making. Next, speakers identify comparable variables in urban scale models that correlate inputs with results. Using Manhattan as a case study, we share a framework for renewable energy-based urban planning. Finally, the authors examine how optimal control of battery sizes can promote equity in energy access.

1. Optimal Sizing of Integrated Community Energy Systems Considering Equity Constraints

Christoph Gehbauer¹, Yulun Wu², James Brown¹ and Michael Sohn, Ph.D.¹, (1)Lawrence Berkeley National Laboratory, Berkeley, CA, (2)University of California, Berkeley, CA

2. Derivation of Comparative Variables for Energy Model Calibration using Data-driven Method

HyeGi Kim and Sun Sook Kim, Ph.D., Member, Ajou University, Suwon, Korea, Republic of (South)

3. Using Measured Building Energy Data to Infer Building Type For Urban Building Energy Modeling

Brett Bass¹, Evan Ezell² and Joshua New, Ph.D., Member³, (1)Oak Ridge National Laboratory, Oak Ridge, TN, (2)University of Tennessee, TN, (3)Oak Ridge National Laboratory, Knoxville, TN

4. Infomorphism: An Urban Planning Framework for Local Renewable Energy Integration

Fengqi Li, Kristen Schell, Haolin Yang and Alexandros Tsamis, Rensselaer Polytechnic Institute

5. Data-Driven Machine Learning Model Performance of Real Annual Natural Gas Consumption in Residential Buildings

Matthias Y.C. Van Hove, Ghent University, Belgium

3:30 PM - 5:00 PM

Paper Session 7 (Intermediate)

Building Operation, Performance and Controls

Room: Monroe Room

Chair:

Building performance depends on not only how the building is designed but also how the building is operated. In this regard, it is important to improve building operational performance by optimal controls, automatic fault detection and diagnosis, and machine learning. The first three papers cover input data uncertainty, sensor faults and the use of collected data for optimal building controls. The fourth paper investigates the dual fuel heat pump controls for energy and cost savings in residential buildings. Finally, the 5th paper presents the optimal demand response control for heat pump water heaters.

1. Development of Demand Response Control Schedules of Heat Pump Water Heaters for California Residential Code Compliance

Aaron Boranian, BEMP, Associate Member¹, Ben Larson² and Bruce A. Wilcox, P.E., Member³, (1)Big Ladder Software, Denver, CO, (2)Larson Energy Research, Menomonie, WI, (3)Bruce A. Wilcox, Berkeley, CA

2. Evaluating the Impacts of Weather Forecast Inaccuracy on Performance of Model Predictive Control for Dynamic Facades

Peter Grant and Christoph Gehbauer, Lawrence Berkeley National Laboratory, Berkeley, CA

3. Incipient Sensor Fault Impacts on Building Performance through HVAC Controls

Yanfei Li, Ph.D., Associate Member, Yeobeom Yoon and Piljae Im, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

4. Potential Heating Energy and Cost Savings of Dual Fuel Heat Pump Control as a Retrofitting Method for Residential Buildings in the U.S.

Yeobeom Yoon¹, Yanfei Li, Ph.D.¹, Piljae Im, Ph.D., Member¹ and James Lyons², (1)Oak Ridge National Laboratory, Oak Ridge, TN, (2)Newport Partners LLC, Davidson, MD

5. Evaluating the Performance of Chiller Plant Efficiency Using Random Forest Model: A High-Rise Building Case Study

Behzad Salimian Rizi, Student Member¹, Mohammad Heidarinejad, Ph.D., P.E., Associate Member¹, Greg Pavlak, Ph.D., Member² and Vincent Cushing³, (1)Illinois Institute of Technology, Chicago, IL, (2)Penn State University, State College, PA, (3)QCoefficient, Inc., Chicago, IL

3:30 PM - 5:00 PM

Seminar 8 (Advanced)

Building Envelope Performance and Design Considerations for Mechanical Engineers

Room: Chicago Room

Sponsor: 7.6 Building Energy Performance

Chair: *Ali Yalaz, P.E., Simpson Gumpertz & Heger, New York, NY*

High-performance buildings require mechanical systems that reduce energy consumption while maintaining indoor air quality. To achieve this, mechanical engineers must understand the role of building envelopes towards overall building performance. This seminar will define key design considerations of high-performance building envelope systems and address common missteps regarding building envelope performance values for energy models. Specifically, we will review fenestration and spandrel U-factor calculations, envelope thermal bridges and thermal comfort, mechanical system impact on surface condensation, and review envelope air leakage assumptions. The seminar includes case studies to provide practical examples of each topic.

1. Condensation Considerations for Mechanical Engineers

Corey C. Wowk, AIA, Simpson Gumpertz & Heger, New York, NY

2. Thermal Bridge Considerations for Mechanical Engineers

Cheryl Saldanha, P.E., Simpson Gumpertz & Heger, New York, NY

3. U-Value Considerations for Mechanical Engineers

Leonidia M. Garbis, P.E., Simpson Gumpertz & Heger, New York, NY

4. Air Leakage Considerations for Mechanical Engineers

Ali Yalaz, P.E., Simpson Gumpertz & Heger, New York, NY

3:30 PM - 5:00 PM
Seminar 9 (Intermediate)

Unique Topics

Room: Water Tower Parlor

Chair: John Bynum, Ph.D., Member, ARUP, Dublin, Ireland

This session covers several topics including CFD for grow houses, inequities in building energy use, lighting for demand response, and strategies for balancing IAQ and energy consumption. The first presentation introduces an approach using CFD to optimize grow house designs for plant growth. The second is a review of recent research on inequities in building energy use and guidance for how professionals can drive change. The third outlines the potential for using lighting as a distributed energy resource via demand response signals. The fourth is an evaluation of different contaminant removal strategies balancing indoor air quality and energy consumption.

1. Utilizing CFD to Optimize Grow House Building Designs

Chaitanya Johar, P.E., Associate Member, AAON, Inc, Tulsa, OK

2. What the Energy Modeling Community Can Do to Minimize Inequalities in Building Energy Usage

Bryce Cox, P.E., BEMP, Member, University of Wisconsin Platteville, Platteville, WI

3. How Can Demand Curves be Used to Configure Connected Lighting Systems to Respond to Openadr Signals?

Shat Pratoomratana and Michael Poplawski, Associate Member, Pacific Northwest National Laboratory, Portland, OR

4. Evaluating Ventilation Strategies to Balance the Indoor Quality Needs and Energy Consumption

Wangda Zuo, Ph.D., Member, Pennsylvania State University, State College, PA

Thursday, September 15

Thursday, September 15, 8:10 AM - 9:00 AM

Keynote

Luke Leung

Luke is a LEED Fellow; a member of ASHRAE COVID19 task force; AIA Task Force on COVID-19; Chair of “Environmental Health Committee”; Member, Expert Peer Review Committee for Council on Tall Buildings and Urban Habitat; Former Board of Directors for USGBC, Illinois; Former Chairman of ASHRAE Technical Committee on “Tall Buildings”; ASHRAE Distinguished Lecturer; Industrial Professional Advisory Council Pennsylvania State University Architectural Engineering School; Industry Advisory Board for IN2 start-up incubator program with National Renewable Energy Laboratory. He is the wide firm Director of the Sustainability Engineering Studio for Skidmore, Owings and Merrill LLP.

Thursday, September 15, 9:10 AM - 10:10 AM

Debate (Intermediate)

It’s Time to Revise the Standard Thermal Comfort Zone of ASHRAE Standard 55

Room: Chicago Room

Chair: Alexandra R. Rempel, Ph.D., University of Oregon, Eugene, OR

With summer comes air-conditioning, and for many, that means packing an extra sweater to keep the goosebumps at bay. Winter can be equally challenging, as people in cold climates swelter in offices warmed to a toasty 72F. Is it possible that the ASHRAE 55 standard comfort zone is due for an update? The urgency of addressing climate change, the high energy consumption of space heating and cooling and the limited research base supporting the standard comfort zone suggest that, perhaps, it could be. In this debate, we’ll hear experts in the field debate the resolution.

9:10 AM - 10:10 AM

Paper Session 8 (Intermediate)

Building Envelope Design, Daylighting and Energy Performance

Room: Monroe Room

Chair: Nathaniel Jones, Pacific Northwest National Laboratory

This session includes three papers which cover diverse but highly interesting topic. This session starts off with a presentation which explores visual comfort and daylight performance of an office building through metrics including sDA and ASE. The next presentation in this session evaluates how algae bio-reactive building envelopes can regulate a building’s natural lighting and demonstrates the significance of self-adaptive shading to a building’s heat gain and energy savings. The final presentation in this

session introduces climate adaptive opaque building envelopes (CABEs) which dynamically exchange heat between indoor and outdoor environments to reduce energy demands for heating and cooling.

1. Algae Bio-reactive Building Envelope: Dynamic Lighting and Energy Aspects for Algae-based Building Skin

Jingshi Zhang¹, Alexandros Tsamis² and Daniel Rosenberg³, (1)The Pennsylvania State University, (2)Rensselaer Polytechnic Institute, (3)Carnegie Mellon University, Pittsburgh, PA

2. Simulation Analysis as a Tool to Obtain Indoor Environmental Quality and Energy Efficiency in Tropical Climate Buildings at an Early Stage Design

Larissa Azevedo Luiz, Caroline Viana de Souza, Pedro Caio Rossi and Raquel San Sanches, Ca2 Consultores, Brazil

3. Modeling, Simulation and Evaluation of a Double-Sided Hydronic Layer Embedded Opaque Climate-Adaptive Building Envelope

Youngjin Hwang¹, Amogh Wasti¹, Theodorian Borca-Tasciuc¹, Justin Scott Shultz, Ph.D., Associate Member², Luigi Vanfretti¹ and Alexandros Tsamis¹, (1)Rensselaer Polytechnic Institute, (2)EYP Architecture & Engineering, Washington, DC

9:10 AM - 10:10 AM

Seminar 10 (Intermediate)

Approaches to Modeling Future Weather, Climate and Extreme Events II

Room: Adams Room

Chair: Jill Kurtz, Page, Houston, TX

This session covers approaches to modeling future weather, climate, and extreme events. The first topic outlines data, analytics, and evaluation methodologies to identify populations that are especially vulnerable to extreme heat events, and possible mitigation strategies in both the long term and short term. The next topic visualizes and explore the nuances of different weather files, discuss their use in typical applications, and provide guidance on common mistakes. The final presentation explores a case study on solar heat gain coefficients to align building design with future energy generation, optimizing for both total and “net” annual electric demand.

1. Urban Thermal Diagnostics and Extreme Heat Vulnerability in Underrepresented Communities

Hala Alfulih, WSP, Chicago, IL

2. Right Weather for the Right Modelling Application: What, How and Where?

Nishesh Jain, Ph.D., Member, University College London / DesignBuilder Software, London, United Kingdom

3. Aligning Building Design with Future Energy Generation: Case Study of Solar Heat Gain Coefficients

Holly Samuelson, AIA, Member¹ and Amir Baniassadi, Ph.D.², (1)Harvard Graduate School of Design, Cambridge, MA, (2)Harvard Medical School, Boston, MA

9:10 AM - 10:10 AM

Seminar 11 (Intermediate)

Modeling Advances: Tools and Workflows II

Room: Water Tower Parlor

Chair: John Bynum, Ph.D., Member, ARUP, Dublin, Ireland

This session introduces modelling advances related to climate data, u-value calculations, and empirical validation of Building Performance Simulation (BPS) programs. The first presentation presents a detailed comparison of climate data derived from 5 ground stations and satellite data including simulation results for a prototype commercial office building. The second presentation presents a method for quantifying the discrepancy between measured and catalog-based U-value calculations. The third presentation focuses on the development and steady-state application of a test facility designed for empirical validation of thermal fabric models that seeks to help bring empirical validation to standard software evaluation procedures.

1. Contrasting Ground Station Vs Satellite Climate Data Impacts on Building Simulation

Drury Crawley, Ph.D., BEMP, Fellow Life Member¹ and Linda Lawrie, Member², (1)Bentley Systems, Inc., Washington, DC, (2)DHL Consulting LLC, Pagosa Springs, CO

2. Filling the Gap: Measured Composite Envelope U-Values and How We Usually Calculate Them

Jeannie Kim, Ph.D., BEMP, Member¹, Joel Neymark, P.E., Member² and Ralph Muehleisen, Ph.D., P.E., Member¹, (1)Argonne National Laboratory, Lemont, IL, (2)J. Neymark & Associates, Golden, CO

3. Empirical Validation with ETNA Data: In the Beginning

Joel Neymark, P.E., Member, J. Neymark & Associates, Golden, CO

Thursday, September 15, 10:30 AM - 12:00 PM

Panel (Basic)

Embodied Carbon of MEP Systems

Room: Chicago Room

Chair: Ivan Jose, McKinstry, Seattle, WA

This panel will be a discussion on the embodied carbon of MEP systems. The panel includes industry experts from mechanical design firms that have worked on studies for projects on understanding the impact of MEP embodied carbon and refrigerants. The panel will also include a leader in the MEP 2040 Challenge, an initiative started by the Carbon Leadership Forum that sets commitments for firms to lower the embodied carbon of MEP systems. The panel will also include a member of the City of Chicago's decarbonization task force, discussing future policy decisions that can help lower a building's whole life carbon.

1. Embodied Carbon of MEP Systems 1

Luke Leung, P.E., BEMP, Member, Skidmore, Owings, & Merrill LPP, Chicago, IL

2. Embodied Carbon of MEP Systems 2

Kathleen Hetrick, BuroHappold

3. Embodied Carbon of MEP Systems 3

Drew Nitschke, Glumac

10:30 AM - 12:00 PM

Paper Session 9 (Intermediate)

Lifecycle Carbon Assessment

Room: Adams Room

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

Understanding the carbon footprint of buildings is essential to reducing carbon emissions and combating climate change. This session details new techniques for quantifying embodied carbon and presents two case studies that examine the embodied carbon of building materials.

1. Operational Carbon Emission Methodology Literature Review

Nathan Vader, Atelier Ten

2. A Decarbonization Proforma of Modular Building Solutions

Noah Benjamin Conrad Klammer¹, Ankur Podder¹, Kaufman Zoe² and Shanti D. Pless, Member³, (1)Affiliated Engineers, Inc., (2)National Renewable Energy Lab, Golden, CO, (3)National Renewable Energy Laboratory, Golden, CO

3. Realistic Estimation of CO2 Emission Reductions Due to Building Retrofit

Yingli Lou¹, Yunyang Ye, Ph.D., Associate Member², Wangda Zuo, Ph.D., Member³ and Yizhi Yang¹, (1)University of Colorado, Boulder, (2)Pacific Northwest National Laboratory, PORTLAND, OR, (3)Colorado University at Boulder, Boulder, CO

4. Locking in Carbon Reduction: A Life Cycle Assessment Case Study

Yogitha Miriyala¹, Amanda Thounaojam¹, Prasad Vaidya¹ and Sanjay Prakash², (1)Indian Institute for Human Settlements, Bangalore, India, (2)Studio for Habitat Futures, New Delhi, India

5. Heuristic Urban-Scale Life Cycle Assessment of Districts to Determine their Carbon Footprints

Maximilian Schildt, Johannes Linus Cuypers, Avichal Malhotra, Maxim Shamovich, Jérôme Frisch, Ph.D. and Christoph van Treeck, Ph.D., Institute of Energy Efficiency and Sustainable Building (E3D), RWTH Aachen University, Germany

Paper Session 10 (Intermediate)

Advances in Modeling Tools, Approaches and Workflows

Room: Monroe Room

Chair: Yunyang Ye, Ph.D., Associate Member, Pacific Northwest National Laboratory, PORTLAND, OR

This session introduces developments and innovation in modeling tools and workflows. The first presentation discusses the development of occupancy schedules for school buildings. The second presentation introduces a python-based tool for pre-simulation validation of space boundaries and a semi-automatic process for correction of errors. The next speaker discusses a new set of tests for ASHRAE Standard 140. This is followed by a presentation on the development of a new VRF heat pump. Finally, we talk about the HVAC control modeling tools and control sequence implementations based on ASHRAE RP 1711.

1. Development of an Occupancy Schedule for OpenStudio Prototype College Building Model

Yeonjin Bae, Ph.D., Associate Member, Yeobeom Yoon, Sungkyun Jung, Ph.D., Mini Malhotra, Ph.D. and Piljae Im, Ph.D., Member, Oak Ridge National Laboratory, Oak Ridge, TN

2. Comparison of a Variable Refrigerant Flow Heat Pump Model in Cooling Mode to Data from ASHRAE HQ

Aziz Mbaye, Member¹ and Massimo Cimmino, Ph.D., P.E.², (1)Polytechnique Montréal, Montréal, QC, Canada, (2)École Polytechnique de Montréal, Montréal, QC, Canada

3. Data Center Chiller Plant: Simulation-based Comparative Control Design Case Study

Grahovac, Milica Grahovac¹, Paul Ehrlich, P.E.², Jianjun Hu¹ and Michael Wetter, Ph.D., Member¹, (1)Lawrence Berkeley National Laboratory, Berkeley, CA, (2)Building Intelligence Group, Afton, MN

4. ASHRAE Standard 140 Weather Drivers Test Suite: Results Analysis

McDowell, Timothy P McDowell¹ and Ralph Muehleisen, Ph.D., P.E., Member², (1)Thermal Energy System Specialists, LLC, (2)Argonne National Laboratory, Lemont, IL

5. Validation of IFC-based Geometric Input for Building Energy Performance Simulation

Richter, Veronika Richter¹, Avichal Malhotra², Eric Fichter¹, Anna Hochberger¹, Jérôme Frisch² and Christoph van Treeck, Ph.D.³, (1)RWTH Aachen University, Institute of Energy Efficiency and Sustainable Building (E3D), Germany, (2)Institute of Energy Efficiency and Sustainable Building (E3D), RWTH Aachen University, Germany, Germany, (3)RWTH Aachen University, Aachen, Germany

10:30 AM - 12:00 PM

Seminar 12 (Intermediate)

Intelligent Building Operations: Efficiencies and Load Management II

Room: Water Tower Parlor

Chair: Aaron Boranian, Associate Member, Big Ladder Software, Denver, CO

This session focuses on new workflows and applications, starting with a progress report on how ASHRAE Standard 205P efficiently and accurately transfers HVAC equipment performance data into simulation programs. It will then discuss a new paradigm for automated output-based verification as well as novel uses of semantic models to map data contained in drawings, naming conventions, contract documents, and maintenance staff knowledge to building analytics applications. Balancing out these new workflows and applications is a case study evaluating the energy performance gains of replacing a conventional chiller-boiler plant with an air-to-water heat pump central plant.

1. A Progress Report on ASHRAE Standard 205P

Charles Barnaby, Fellow Life Member, CSB Consulting, Moultonborough, NH

2. Emission Reduction Retrofit Strategies with Fuel Switching Using Air-to-Water Heat Pump Central Plant Systems

Christopher DesRoches, P.Eng., Member¹ and Krishnan Gowri, Ph.D., BEMP, Fellow ASHRAE², (1)Mitsubishi Electric Sales Canada Inc., Markham, ON, Canada, (2)Intertek Building Science Solutions, Bothell, WA

3. A New Paradigm for Automatically Verifying Control Performance in Building Energy Model

Jeremy Lerond, Affiliate¹, Yan Chen, Ph.D.², Xuechen Lei, Ph.D., Associate Member¹ and Yun Joon Jung², (1)Pacific Northwest National Laboratory, Richland, WA, (2)Pacific Northwest National Laboratory, Portland, OR

4. Using Semantic Models for Enhanced Building Analytics Application

Parastoo Delgoushaei, National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA

Thursday, September 15, 2:30 PM - 3:30 PM

Panel (Basic)

Fishbowl Session

Room: Adams Room

Chair: James Dirkes, Foresight Management, Grand Rapids, MI

This session will be an informal, informative discussion among peers regarding modeling and modeling-related issues that affect us in a major way. The Fishbowl helps facilitate discussion by having 3-4 people in the center of the room, talk at any one time on the specified topic. Audience members are invited to participate by selecting a panelist to replace when they have a question or comment. Topics of discussion include:

- What are your biggest challenges? (Not only techniques, but processes, training, etc.)
- How do you manage multiple projects?
- How are your models used, and how can they become more useful?

Thursday, September 15, 4:00 PM - 5:00 PM

SoapBox Session

Room: Adams Room

Chair: Dennis Knight, P.E., Fellow ASHRAE, Whole Building Systems, LLC, Mt. Pleasant, SC

Friday, September 16

Friday, September 16, 8:10 AM - 9:00 AM

Keynote

Amber Mahone

Implications of Net Zero: Buildings, the Grid, and the Future of Gas

Amber Mahone leads E3's Clean Energy practice area, which specializes in analyzing and modeling longterm greenhouse gas reduction strategies in the energy economy, including a focus on building electrification and future of natural gas questions. She has led California's analysis of greenhouse gas reduction strategies and worked on similar projects focusing on the Northwest, New York, New England, and the entire U.S. Ms. Mahone's expertise ranges from renewable integration, to transportation and building efficiency and electrification, to biofuels and emerging low-carbon technologies. Ms. Mahone holds an M.P.A. from Princeton University and a B.A. in International Relations from Wellesley College.

Friday, September 16, 9:10 AM - 10:10 AM

Panel (Intermediate)

Solution Room

Room: Chicago Room

Chair: Aaron Boranian, Associate Member, Big Ladder Software, Denver, CO

This session presents attendees with an opportunity to interact with their peers and "crowd source" answers to their burning questions. This is the same intent as unmethours.com -- the question-answer forum for building energy simulations -- but offered in a live, interactive, and dynamic format for conference attendees. Participants are given time to think of a challenge they are facing before presenting their problem to a group for brainstorming. This allows participants to seek out as well as provide peer-supported advice on solving each other's challenges. What answers will you find (or give) in Unmet Hours -- LIVE?

9:10 AM - 10:10 AM

Paper Session 11 (Intermediate)

Building Simulation Education and Quality Assurance

Room: Monroe Room

Chair:

This session includes three papers with different but very interesting and important topics. The first paper talks about the integration of building performance simulation into the existing curricula of architectural education. The second paper presents an automated approach to help modelers quality check building energy models at the early design phase. The third paper is an empirical study that compares a passive house to a conventional one in Manhattan, New York, bases on indoor environmental quality and energy consumption.

1. An Automated Approach for Quality Checking Early Design Phase Building Energy Models

Brett Andrew Horin, CannonDesign

2. One Step at a Time: Why Confidence, Familiarity, and Trust are Key to Building Performance Simulation in Architectural Education

Jonathan Yorke Bean and Laura Carr, The University of Arizona

3. I Lived in a Passive House Building: Here's What I Learned

Shemesh, Sigal Shemesh, Buro Happold

9:10 AM - 10:10 AM

Seminar 13 (Intermediate)

Evolving Performance Indicators

Room: Water Tower Parlor

Chair: Walter Grondzik, P.E., Fellow Life Member, Ball State University, Muncie, IN

This session begins with a summary report of the energy use and effectiveness of several combinations of germicidal UV with HVAC systems in mitigating SARS-Cov-2. Assumptions from previous studies are discussed and future research suggested. The second presentation addresses the limitations of EUI (energy use intensity) as a performance indicator and provides suggestions for an alternative metric derived through analysis involving 800 simulations of various building configurations. This is followed by a proposal to consider additional, non-tradition metrics when engaged in the design and planning of cities—with a focus on the reduction of negative environmental impacts.

1. Comparing the Energy Use and Effectiveness of Upper Room Germicidal Ultraviolet Radiation and HVAC Strategies to Combat Sars-Cov-2

Belal Abboushi, Pacific Northwest National Laboratory, Portland, OR

2. Normalization of Building Energy Use Under Different Locations and Occupant Densities

Young-Seo Yoo¹, Dong-Hyuk Yi, Ph.D.², Deuk-Woo Kim, Ph.D.³ and Cheol-Soo Park, Ph.D.¹, (1)Department of Architecture and Architectural Engineering, Seoul National University, Seoul, Korea, Republic of (South), (2)System & Energy Division in Korea Testing Laboratory, Korea, Republic of (South), (3)Department of Building Energy Research in Korea Institute of Civil Engineering and Building Technology, Korea, Republic of (South)

3. Performance Analytics of Net Zero City

Sukreet Singh, BEMP, Cuningham, Las Vegas, NV

9:10 AM - 10:10 AM

Seminar 14 (Intermediate)

Innovations in Passive and Hybrid Heating and Cooling II

Room: Adams Room

Chair: Alexandra R. Rempel, Ph.D., University of Oregon, Eugene, OR

Wind, sunlight, solar heat, cool night air, and cold night skies are the renewable energy sources featured in this session, highlighting their potential to free the renewably-powered grid for uses that require electricity. Capturing and using these climatic resources to their greatest advantage through intelligent controls and optimizations is a rapidly evolving field, explored here in high desert, subtropical, Mediterranean, and cold continental climates.

1. Design of Murbs in a Hot and Dry Climate through Integrative Environmental Analysis

Haobo Liu¹ and Saurabh Shrestha², (1) DIALOG Design, Vancouver, BC, Canada, (2) DIALOG Design, Toronto, ON, Canada

2. Outdoor Educational Spaces: Generative Shading Design for a Warming Climate

Mili Kyropoulou, University of Houston, Houston, TX

3. Hybrid Cooling with Operable Electrochromic Windows

Ranojoy Dutta, BEMP and HBDP, Associate Member, 1529, SAN JOSE, CA

Friday, September 16, 10:30 AM - 12:00 PM

Paper Session 12 (Intermediate)

Simulation Calibration and Validation

Room: Monroe Room

Chair: Jian Zhang, Pacific Northwest National Laboratory, Richland, WA

Building simulation plays an important role in making informed decisions on building retrofits. When applying simulation models for existing buildings, the models need to be calibrated and validated against real operation data. This session discusses OpenStudio model calibration for a cross laminated timber building. The session also covers the EnergyPlus model validation for the Net-Zero Energy Residential Test Facility at NIST. The third paper investigates the use of a calibrated building model to certify a net positive energy building during the pandemic. The final paper presents a decision-support framework to maximize the retrofit impact for government-owned public buildings.

1. Empirical Validation of Whole Building Energy Simulation Program under Free-Floating Conditions

Hyojin Kim, Ph.D., Member¹, Elizabeth Scacifero¹, Minkyong Park¹, Piljae Im, Ph.D., Member², Lisa Chen Ng, Ph.D.³, Brian Dougherty, P.Eng.³ and William V. (Vance) Payne, Ph.D., Member³, (1) New Jersey Institute of Technology, Newark, NJ, (2) Oak Ridge National Laboratory, Oak Ridge, TN, (3) National Institute of Standards and Technology, Gaithersburg, MD

2. Operating and Certifying a Net Positive Energy Building During a Pandemic

Jung-Ho Lew, Georgia Institute of Technology

3. Highly Instrumented Cross Laminated Timber Building: Sub-metering from Panels to Desks

Gabriel Flechas, Student Member, Paulo Cesar Tabares-Velasco, Ph.D., Associate Member and Gabe Fierro, Ph.D., Colorado School of Mines, Golden, CO

4. Decision Support Framework for the Retrofit of Public Buildings for Energy and Carbon Reduction
Baliga, Rashmi Baliga¹ and David Conant-Gilles², (1) Affiliated Engineers, Inc, (2) Affiliated Engineers, Inc.

10:30 AM - 12:00 PM

Seminar 15 (Intermediate)

An Overview of Simplified Energy Modeling Approaches and Tools: Industry Applications

Room: Chicago Room

Chair: Andrea Mengual, P.E., Pacific Northwest National Laboratory, Seattle, WA

Simplified Building Energy Modeling (S-BEM) is an approach to building energy simulation that aims to make energy modeling easier, faster, and more accessible to designers. Although most often used to inform early-stage design decisions, S-BEM is a powerful performance analysis tool that is gaining traction in industry and has the potential to provide an alternative to prescriptive options for incentive programs and code compliance. This session will discuss the motivation behind the development of a simplified modeling ruleset, the Simplified Performance Rating Method, as well as two S-BEM tools that are actively in use today.

1. Lessons Learned from a Decade of Simplified Modeling

Chris Baker, AIA, BEAP and BEMP, Willdan

2. Simplified Performance Rating Method: Testing and Validation Results

Andrea Mengual, P.E., Pacific Northwest National Laboratory, Seattle, WA

3. Sketchbox and Its Applicability in Industry

Ben Heymer, P.E., Member, Slipstream

10:30 AM - 12:00 PM

Seminar 16 (Intermediate)

Modeling Advances: Tools and Workflows III

Room: Water Tower Parlor

Chair: John Bynum, Ph.D., Member, ARUP, Dublin, Ireland

The use of parametric modelling to support building design is becoming more frequent across many disciplines including energy analytics. In this session, two presentations outline uses of parametric modelling: one for early design stage analytics including a case study of a manufacturing facility and another for large parametric studies using prototype models. Additionally, this session includes the presentation of a tool for assessing re-tuning measures in buildings using an EnergyPlus validated modelling procedure. Finally, this session also includes a presentation on the development of energy modelling guidelines specifically tailored to higher education buildings.

1. Standardizing Low Energy Buildings in Higher Education

Ethan Heil, P.E., Member, University of Virginia, Charlottesville, VA

2. Modelkit Flannel Edition: Workflow Automation and Prototype Models for Large Parametric Studies

Peter Ellis, Member, Big Ladder Software, Denver, CO

3. Providing Energy Modelling Tools for Building Owners to Inform Early-Stage Building Design

Annie Marston, Ph.D. and Finlay Milliner, Hydrock Consultants, Bristol, United Kingdom

4. Introducing the Building Re-Tuning Simulator

Nick Fernandez, Associate Member, Pacific Northwest National Laboratory, Richland, WA

10:30 AM - 12:00 PM

Seminar 17 (Intermediate)

Modeling for Carbon and Embodied Energy

Room: Adams Room

Chair: Jill Kurtz, Page, Houston, TX

As jurisdictions continue to put in place fines and other financial incentives to decarbonize the built environment, the calculation of operational and embodied carbon is gaining increased attention among a variety of stakeholders. This session includes four presentations covering early-stage modelling for decarbonizing central plants, real time carbon tracking for a university seeking to meet its target of becoming carbon neutral by 2030, and the use of Cambium in estimating operational carbon during the design process. The fourth presentation covers the use of ice storage to shifting heat pump electrical load based on grid capacity and carbon emissions.

1. Tale of Two Central Plants: Energy Efficiency and Carbon Emission Calculations Informed By “Lite Modeling”

Amir Rezaei-Bazkiaei, Ph.D., BEMP, Associate Member¹ and Colin Hale², (1) CannonDesign, Buffalo, NY, (2) CannonDesign, St Louis, MS

2. Carbon Cents - a Clemson University & Rmf Partnership to Provide Carbon Use Tracking and Real Time Systems Adjustment to Reduce Energy

Miles Martschink Jr., P.E., Member¹ and Tim Howard², (1) RMF Engineering, Clemson, SC, (2) Clemson University, Clemson, SC

3. Ice Heating

Brian McKinney, BEMP, Associate Member, Jaros Baum & Bolles, New York, NY

4. Estimating Operational Carbon in Building Designs

Chris Savage, AIA, Associate Member, LMN Architects, Seattle, WA