2022 Annual Conference

June 25th - June 29th, 2022

Sheraton Centre Toronto
Toronto, Ontario Canada

Technical Program

Updated: June 8, 2022

Sunday, June 26

Sunday, June 26, 8:00 AM - 9:00 AM
Conference Paper Session 1

Building Modeling Research

Track: Research Summit

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Room: Osgoode (LC)
Chair: Peng Yin, University of Louisiana at Lafayette, Lafayette, LA

Building energy modeling can be a powerful tool for the design and evaluation of new building architectures, systems, and materials. This session features papers on recent research advances in the field of building energy modeling, including the development and demonstration of new building energy modeling tools.

Learning Objectives:

1. Understand calibration and prediction with uncertainties using Bayesian inference
2. Know what the BIR-BEM auto-calibration platform is and how to use it
3. Explain how the EMPD algorithm can be used inside OpenStudio
4. Describe challenges in modeling mass timber buildings.
5. Understand the role of Primary Energy Factors (PEF) to convert final (site) energy to primary (source) energy use
6. Derive simple correlations for the time evolution of PEF for building stock modeling & assessment of efficiency measures

1. A New Bayesian Inference R Platform for Building Energy Model Calibration (TO-22-C001)
Danlin Hou, Student Member[1], *Ibrahim Hassan, Ph.D., P.E., Member*[2] *and Leon Wang, Ph.D., Member*[1], *(1)Concordia University, Montreal, QC, Canada, (2)Mechanical Engineering Department, Texas A&M at Qatar, Doha, Qatar*

2. EMPD Openstudio Measure for Mass Timber Buildings (TO-22-C002)
Gabriel Flechas, Student Member *and Paulo Tabares Velasco, Ph.D., Associate Member, Colorado School of Mines, Golden, CO*

3. Predicting Primary Energy Factors for Enhanced Projections of Energy Savings in Building Stock Modeling (TO-22-A001)
Constantinos A. Balaras, Ph.D., Fellow ASHRAE*, Elena Dascalaki, Ph.D. and Ioanna Psarra, Institute for Environmental Research & Sustainable Development, NOA, Athens, Greece*

8:00 AM - 9:00 AM

Seminar 1 (Basic)

ASHRAE Conference Crash Course

Track: Professional Development and Education
Room: Dominion South (2)
Sponsor: YEA
Chair: Madison Schultz, P.E., Member, OK BeCo, Oklahoma City, OK
First time at an ASHRAE Conference? Been coming for years, but still confused? What is a TC? What is a Standing Committee? Who can attend what? What is the AHR Expo? And why is all this happening at once? This crash course provides all attendees with an introduction to all the ASHRAE Conference activities, explains how you can get involved, and allows you to ask questions to experienced attendees.

Learning Objectives:

1. Explain ASHRAE's organizational structure
2. Identify ASHRAE's standing committees and technical committees.
3. Explain how to use the ASHRAE Conference Application
4. Identify ASHRAE Conference Social and Networking Events, and the opportunities available through the ASHRAE Learning Institute
5. Understand the basic structure and organization of ASHRAE.
6. Successfully navigate the conference.

1. The Ins and Outs of ASHRAE
Elizabeth Jedrlinic, Member*, Trane Technologies, Plainview, NY*
2. Make the Most of Your Conference Experience
Chris Krieps, P.E., Member*, Salas O'Brien, Chicago, IL*

8:00 AM - 9:00 AM

Seminar 2 (Basic)

Reimagining the Old, Inventing the New: Tools and Strategies for Decarbonizing Buildings with District HVAC Systems Around the World

Track: HVAC&R Systems and Equipment
Room: Provincial (2)
Sponsor: 7.3 Operation, Maintenance and Cost Management, 6.2 District Energy, TC 6.1, MTG.EBO
Chair: Sonya Pouncy, Member, Building Vitals, Detroit, MI
Around the world, district HVAC systems are regaining popularity as one of the many effective strategies to decarbonize buildings. These systems can often rely on economies of scale to gain efficiencies and reduce energy consumption. However, they can also present uncommon challenges in their design, operation and maintenance. This seminar explores ways that district or network systems are being reimagined, traditional asset management tools are being rediscovered and new tools are being introduced in support of efforts to achieve net zero by 2050.

Learning Objectives:

1. Explain the role that heat networks (district heating) play in the decarbonization agenda for the UK and other countries
2. Explain the basic concepts and benefits of Modelica language-based modeling
3. Identify opportunities in model-based optimization for district cooling systems
4. Utilize a BMS and other computerized asset management tools to decarbonize and optimize performance to reduce energy and water consumption
5. Explain the role that heat networks (district heating) play in the decarbonization agenda for the UK
6. understand the range of activities and support in the UK for district heat networks
7. Explain the basic concepts and benefits of Modelica language-based modeling
8. Identify opportunities in model-based optimization for district cooling systems

1. Current District Heating Trends in the UK: An Update on Government Support and Research
***Joel Hamilton**, UK Government, London, United Kingdom*

2. Open Source Modelica Models for Optimal Design and Operation of District Cooling Systems
***Wangda Zuo, Ph.D., Member**, Pennsylvania State University, State College, PA*

8:00 AM - 9:00 AM

Seminar 3 (Intermediate)

Weather Modeling Tools for Buildings in a Changing Climate

Track: Cold Climate Building System Design, Operation and Resilience
Room: Sheraton C (LC)
Sponsor: 4.2 Climatic Information, 2.5 Global Climate Change
Chair: Carlo Bianchi, Ph.D., Member, National Renewable Energy Laboratory, Golden, CO
In a fast-evolving climate, accurate weather boundary conditions represent a key element for accurate building energy modeling. This seminar presents two innovative tools to model weather data in future scenarios and in urban environments.

Learning Objectives:

1. Explain the importance of future weather boundary conditions in climate driven resilience and efficiency analysis
2. Explain why a stochastic framework is needed to assess resilience versus efficiency combined assessments
3. Describe VCWG modeling paradigm and sub-modules: the rural, rural surface energy-water balance, building energy, surface energy-water balance, soil energy-water balance, vertical diffusion, and urban boundary layer models
4. Describe preparation of weather data as boundary and forcing conditions for BEMs: observed weather files, meso-scale models, and downscaling of climate models to produce weather files
5. Understand the importance of future weather boundary conditions in climate driven resilience and efficiency analysis.
6. Understand why a stochastic framework is needed to assess resilience versus efficiency combined assessments.
7. Describe VCWG modeling paradigm and sub-modules: the rural, rural surface energy-water balance, building energy, surface energy-water balance, soil energy-water balance, vertical diffusion, and urban boundary layer models
8. Describe preparation of weather data as boundary and forcing conditions for BEMs: observed weather files, meso-scale models, and downscaling of climate models to produce weather files

1. Acute Climate Driven Severe Weather: The Multi-Scenario Extreme Weather Simulator
***Daniel L. Villa, P.E., Member**, Sandia National Laboratories, Albuquerque, NM*

2. Toward New Paradigms in Building Energy Modeling
***Amir A. Aliabadi, Ph.D., P.E.**, University of Guelph, Guelph, ON, Canada*

8:00 AM - 9:00 AM

Seminar 4 (Intermediate)

What Happened to our Hospitals after the COVID-19 Fiasco? HVAC Design, Control and Operation

Track: Buildings in the Aftermath of COVID-19
Room: Grand East (LC)
Sponsor: 1.4 Control Theory and Application, 7.5 Smart Building Systems, TC 1.5, TC 9.6, TC 4.10
Chair: Frank Shadpour, P.E., Fellow ASHRAE, SC Engineers, Inc., San Diego, CA
Most of our hospitals survived the COVID-19 fiasco; and, quite frankly, we don't know how. Every hospital scrambled to remain operational, including providing makeshift negative pressure rooms to safeguard its occupants to the extent possible. Now what? We need to plan for the battles of the future rather than focusing on the wars of the past. This seminar focuses on the lessons learned and presents the latest technology for the proper design, control, and operation of hospitals. New standards regarding air changes per hour, filtration and building automation are among the topics of discussion.

Learning Objectives:

1. Describe the current codes and regulations that govern HVAC design for hospitals
2. Explain how more aggressive air change rates can assure a higher quality of infection control
3. Distinguish ways in which the building automation system can make HVAC systems more flexible and adaptive to control airborne infection
4. Explain how natural ventilation can not only enhance safety but enhance the healing environment
5. Describe the current codes and regulations that govern HVAC design for hospitals.

6. Learn how more aggressive air change rates can assure a higher quality of infection control.
7. Distinguish ways in which the building automation system can make HVAC systems more flexible and adaptive to control airborne infection.
8. Explain how natural ventilation can not only enhance safety but enhance the healing environment
9. Learn about indoor air quality (IAQ) and how assessments can be used to validate IAQ in hospitals and medical office buildings.
10. Define engineering controls strategies to remove hazardous conditions.
11. Understand the application of negative pressure rooms.
12. Learn how building controls can be easily modified to control spaces.

1. The Hospital of the Future: Designing for Energy Efficiency and Infection Control
***Timothy Jacoby**, Scripps Health, San Diego, CA*

2. The Hospital of the Future: Designing Flexible and Adaptable HVAC Systems
***Sandy Renshaw, Member**, Kaiser Permanente, San Diego, CA*

8:00 AM - 9:00 AM

Forum 1 (Intermediate)

Roadblocks in the Expanding Use of Hydrogen for Building Decarbonization and What This Means for ASHRAE

Track: Research Summit
Room: Dominion North (2)
Sponsor: 6.10 Fuels and Combustion
Chair: Thomas Butcher, Ph.D., Fellow ASHRAE, Brookhaven National Laboratory, Upton, NY
There is increasing interest and active research and demonstration work on the use of hydrogen as a low-carbon fuel in buildings. Testing has shown blends to 20% might be used without equipment changes but the future vision is for 100% hydrogen. Use of blends at any level present to the industry significant challenges including changes in: burner design, building safety protocols, building codes, and equipment safety and performance standards. This forum focuses on: how should ASHRAE respond to these challenges? Impact on handbook, methods of test, other publications, and potentially, ASHRAE research is included.

Sunday, June 26, 9:45 AM - 10:45 AM

Virtual Paper Session (Basic)

Data and Simulations to Improve HVAC and Thermal System Operations

Track: HVAC&R Systems and Equipment
Chair: Raul Simonetti, Member, Carel Industries SpA, Brugine, Italy
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Learning Objectives:

1. Understand the methods that can be used to reverse fouling in membrane-based energy exchangers
2. Identify the impact of two fouling reversal methods
3. Understand the methodology that can be used to calculate the uncertainty in fluid dynamic gauging measurements
4. Delineate the major sources of uncertainties that affect the performance of fluid dynamic gauging instruments
5. How many sensors are required to be deployed in the data center.
6. Investigation of a method to evaluate the distribution of environmental conditions in a data center by treating them as images.
7. After attending this session, the attendees will be able to describe the FCU fault impacts and the ranked faults.
8. After attending this session, the attendees will be able to apply the bottom-to-up fault impact analysis method.

1. Effect of the Changes in Boundary Conditions on the Reversibility of Crystallization Fouling in a Liquid-to-Air Membrane Energy Exchanger (TO-22-C044)
***Adesola Olufade, Ph.D., Member**[1], Bicheng Xing, Associate Member[2] and Carey Simonson, Ph.D., P.E., Member[2], (1)AccuraSEE Instruments, Saskatoon, SK, Canada, (2)University of Saskatchewan, Saskatoon, SK, Canada*

2. Uncertainty Assessment of a Fluid Dynamic Gauging Instrument (TO-22-C058)
***Adesola Olufade, Ph.D., Member**[1] and Lei Zhang[2], (1)AccuraSEE Instruments, Saskatoon, SK, Canada, (2)University of Regina, Regina, SK, Canada*

3. Prediction of Spatial Distribution in Data Center by Super Resolution Convolutional Neural Network, for Controlling Air Conditioning System: How Much the Number of Sensors Can be Reduced? (TO-22-C018)
Yuki Sogawa[1], *Hiroki Tsukamoto*[1], *Morito Matsuoka*[1], *Mikio Kagawa*[2] *and Kazuhiro Frusho*[2], *(1)Osaka University, Osaka, Japan, (2)Daikin Industries, Ltd., Osaka, Japan*

4. A Simulation-Based Method to Analyze Fan Coil Unit Fault Impacts (TO-22-C023)
Yimin Chen, Ph.D., Associate Member[1], *Guanjing Lin, Ph.D., Associate Member*[1], *Zhelun Chen, Ph.D., Associate Member*[2], *Jin Wen, Ph.D., Member*[2] *and Jessica Granderson, Ph.D.*[1], *(1)Lawrence Berkeley National Laboratory, Berkeley, CA, (2)Drexel University, Philadelphia, PA*

9:45 AM - 10:45 AM

Conference Paper Session 2

COVID and Healthcare

Track: Buildings in the Aftermath of COVID-19

NY PDH G

Room: Osgoode (LC)
Chair: Mahroo Eftekhari, Ph.D., Member, Loughborough University, Loughborough, United Kingdom
The COVID pandemic has focused a sharp light on HVAC systems and their roles in both spreading and mitigating the spread of airborne pathogens. The papers in this session discuss utilization of HVAC systems for mitigation.

Learning Objectives:

1. Understand the importance of indoor airflow patterns on the transmission of airborne pathogens
2. Understand how CFD analysis can help in optimizing the HVAC layout for upper room UVGI applications.
3. Describe the clinical and environmental results associated with complete remediation of airborne pathogens and fungal VOCs in a hospital setting.
4. Describe the clinical and environmental results associated with complete remediation of airborne pathogens and VOCs in a long term care setting.
5. Identify and manage areas of high risk for airborne pathogen spread in an occupied space.
6. Understand how simple and effective HVAC-based strategies can be applied to mitigate the spread of COVID-19.

1. Computational Fluid Dynamics (CFD) Analysis of Impact of HVAC Layout on the Performance of Ultraviolet Germicidal (UV-C) to Control the Probability of Infection Due to Transmission of Airborne Pathogens (TO-22-C003)
Kishor Khankari, Ph.D., Fellow ASHRAE[1] *and William Bahnfleth, Ph.D., P.E., Presidential Fellow ASHRAE*[2], *(1)AnSight LLC, Ann Arbor, MI, (2)Penn State, University Park, PA*

2. The Effects of Air Purification Technology on Environmental and Clinical Metrics in Two Healthcare Settings (TO-22-C004)
Kathryn C. Worrilow, Ph.D., Associate Member[1], *Stanislaw P. Stawicki*[2], *Susan Schlener*[3], *Alicia R. Urrutia*[1] *and Charles Kimble*[1], *(1)LifeAire Systems, Allentown, PA, (2)St. Luke's University Health Network, Bethlehem, PA, (3)Phoebe Ministries Allentown Campus, Allentown, PA*

3. HVAC Strategies for Mitigating the Spread of COVID-19 in a Canadian Long-Term Care Home (TO-22-C005)
Monica Brands, Student Member[1], *Khalid Ullah, Student Member*[2], *Adrian Wu*[2], *Amirali Rokn*[2] *and Alan S. Fung, Ph.D., Member*[3], *(1)Toronto Metropolitan University, Toronto, ON, Canada, (2)Ryerson University, Toronto, ON, Canada, (3)Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, ON, Canada*

9:45 AM - 10:45 AM

Conference Paper Session 3

Professional Development: Engineering, Architecture and Project Management

Track: Professional Development and Education

NY PDH

Room: Sheraton C (LC)
Chair: Paul Torcellini, Ph.D., P.E., Fellow ASHRAE, National Renewable Energy Laboratory, Golden, CO
As the many and diverse professions that participate in ASHRAE must continuously work in an ever-changing industry, it is critical that professionals are aware of these changes, and stay up to date and trained on current and future industry needs. This session covers topics associated with professional development in engineering, project management, and architectural backgrounds.

Learning Objectives:

1. Understand the philosophical roles and responsibilities of an engineer and the challenges from the current model of engineering progression
2. Understand a brief history of the profession and the expectations of what it carries, the interactions with the other technical disciplines and the opportunities offered by our advancement
3. After attending this session, the attendees will be able to apply qualitative and quantitative lighting design method to their curriculum.
4. Attendees will be able to design a lighting course that combines simulation and Virtual Reality (VR) tools to assess architectural spaces.
5. apply the Decision Matrix beyond IPD projects in their own project decision making processes
6. better integrate project teams in full-party high-value decision making to deliver better quality solutions for their clients by making process driven optimized decisions.

1. The Philosophy of Engineering (TO-22-C006)
***Chris KW Leung, P.Eng., Member**, Cundall HK Ltd, Hong Kong, Hong Kong*

2. Shaping Light: An Integrative Approach to Teaching Lighting Design in Architecture (TO-22-C007)
***Azadeh Sawyer, Ph.D.** and Jiarong Xie, School of Architecture, Carnegie Mellon University, Pittsburgh, PA*

3. Process Driven Optimized Decision Making in an Integrated Project Delivery (IPD) Environment: Importance of Decision Matrices (TO-22-C008)
***Mudit Srivastava, Associate Member**[1] and **Keith Davidge, Associate Member**[2], (1)Integral Group, Toronto, ON, Canada, (2)Integral group, Toronto, ON, Canada*

9:45 AM - 10:45 AM

Seminar 5 (Advanced)

Designing Control Systems for Net-Zero Energy Buildings and Communities

Track: Connected Buildings, Connected Communities
Room: Dominion North (2)
Sponsor: 1.4 Control Theory and Application
Chair: Paul Ehrlich, P.E., Member, Building Intelligence Group, Afton, MN
Net-zero energy buildings and communities provide great potential to deliver an efficient facility with on-site or remote renewables. Properly designed and controlled these projects can also provide improved resilience and even become "carbon negative." This seminar focuses on design and control optimization of net-zero buildings. A new process for HVAC and controls design called "co-design" is introduced that uses energy models to concurrently make system design and control decisions resulting in balancing of energy use, generation and storage.

Learning Objectives:

1. Explain the current design process and the challenges that it introduces
2. Describe the co-design process, which is already being used in other industries
3. Evaluate how the co-design process can be utilized with net zero energy projects and the added challenges of looking not only at energy use, but also generation and storage
4. Describe case studies of actual projects and how the process can be applied
5. describe how to categorize the load type for resident operation
6. understand the principles of resilient community energy system operation in islanded mode.

1. Integrated System and Control Design for Net-Zero Energy Communities
***Veronica Adetola, Ph.D., Member**, Pacific Northwest National Laboratory, Richland, WA*

2. Optimal Renewable Resource Allocation and Load Scheduling of Resilient Communities
***Wangda Zuo, Ph.D., Member**, Pennsylvania State University, State College, PA*

9:45 AM - 10:45 AM

Seminar 6 (Intermediate)

IEQ and the Building Envelope: When Walls Talk

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Dominion South (2)
Sponsor: 4.4 Building Materials and Building Envelope Performance, 1.12 Moisture Management in Buildings
Chair: Theresa Weston, Member, The Holt Weston Consultancy, LLC, Richmond, VA
The materials and components that comprise the building thermal envelope can have a dramatic effect on indoor environmental quality. Materials are increasingly be evaluated to determine whether they are sources or sinks for environmental contaminants. Moreover, the energy demand and comfort in high performance buildings rely on the design and construction of the building thermal envelope to minimize loads and maximize system efficiency. This seminar focuses on the interaction between the building envelope system and the other building systems and the resulting influence on indoor environmental quality.

Learning Objectives:

1. Describe the topic of traditional IAQ areas which are increasingly being requested of manufacturers and will understand how the movement to full disclosure of materials of manufacture and protection of intellectual property conflict one another.
2. Become familiar with the ever-increasing life cycle considerations of materials in the built environment and healthy building design
3. Define and express the types of important measures involved in calculating building envelope performance.
4. Explain the importance and reasons for the difference between the results simulated by the integrated model and the single models in the field of building envelope performance.
5. This presentation describes the impact of IEQ on building envelope performance.
6. In this presentation, the possibility of developing an integrated model combining energy, indoor air quality and moisture performances models is explained.

1. The Things You Can't See in Your Building Envelope: Indoor Air Quality and Material Health in the Built Environment
Diana Fisler, Ph.D., Member[1] *and Patrick Noonan*[2]*, (1)ADL Ventures, Littleton, CO, (2)Knauf Insulation North America, Shelbyville, IN*

2. Evaluation of IEQ Measures Using an Integrated Model for Building Envelope Performance Analysis
Seyedmohammadreza Heibati[1]*, Wahid Maref, Ph.D., Member*[1] *and Hamed Saber, Ph.D.*[2]*, (1)École de technologie supérieure, University of Quebec,, Montreal, QC, Canada, (2)Jubail University College, Al Jubail, Saudi Arabia*

3. Preventing Condensation at a Leaky and Cold Water Treatment Plant
Peter Adams, P.Eng., Member*, Morrison Hershfield Ltd, Toronto, ON, Canada*

9:45 AM - 10:45 AM

Workshop 1 (Basic)

Developing an ASHRAE Standard/Guideline to Assess the Performance of Occupancy Sensor Systems in Buildings

Track: Research Summit
Room: Provincial (2)
Sponsor: 7.5 Smart Building Systems
Chair: Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI
A broad range of occupancy sensor systems are used in residential and commercial buildings, including for demand controlled ventilation, HVAC control and lighting controls, with the goal of saving energy and improving building performance. However there is not currently a standard methodology to evaluate the performance of occupancy sensor systems, including their reliability. This workshop focuses on a discussion of recent research findings on occupancy sensor reliability and the development of test methods that can be used to evaluate occupancy sensor reliability.

Learning Objectives:

1. Define the importance of occupancy sensors in residential and commercial buildings for use in achieving energy savings
2. Identify key variables that should be evaluated to assess the reliability of occupancy sensors.
3. Discuss and critique the use of key metrics to evaluate occupancy sensor system performance (including both occupancy counting and presence sensors)
4. Identify a path forward to develop a standard/guideline for evaluating occupancy sensor system performance.

5. Define the importance of occupancy sensors in residential and commercial buildings for use in achieving energy savings
6. Discuss and critique the use of key metrics to evaluate occupancy sensor system performance (including both occupancy counting and presence sensors)

1. Commercial Building Occupancy Sensor System Testing
***Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE**, Texas A&M University, College Station, TX*

2. Residential Occupancy Sensor System Reliability Evaluation
***Kristen Cetin, Ph.D., P.E., Member**, Michigan State University, East Lansing, MI*

Sunday, June 26, 11:00 AM - 12:30 PM

Virtual Paper Session (Intermediate)

Smart Building Operation to Support Occupants and Grid Interaction

Track: Connected Buildings, Connected Communities

Chair: Raul Simonetti, Member, Carel Industries SpA, Brugine, Italy

Buildings are increasingly aware of their occupants and the environmental conditions under which they operate. In addition building systems are becoming smarter and more sophisticated to support occupant needs, system operational needs, and grid need. This session includes presentations on advances in occupant comfort, grid-interactivity and system performance improvements in commercial and residential buildings.

Learning Objectives:

1. Provide recommendations for cold climate air source heat pump performance curves in building energy simulation
2. Understand the limitations of using standard air source heat pump performance curves for cold climate air source heat pumps.
3. Understand peak electrical demand implications when replacing fuel fired heating systems with air source heat pumps in marine and cold-humid regions.
4. Describe the driving factors of peak electrical demand when integrating air source heat pumps in a single-family home in marine and cold-humid climates.
5. Understand how sensor placement affect the smart building system performance
6. Understand how climate zone affects building system performance

1. Improvement of Estimation Accuracy of Soil Effective Thermal Conductivity and Ground Heat Exchanger Simulation By Data Assimilation Using Ensemble Kalman Filter (TO-22-C047)
***Yutaka Shoji**, Takao Katsura, Ph.D., Associate Member and Katsunori Nagano, Ph.D., Hokkaido University, Sapporo, Japan*

2. Development of Variable-Capacity Air-Source Heat Pump Performance Adjustment Curves for Building Simulation (TO-22-C012)
***Alex Lachance**[1], Justin Tamasauskas[2] and Stéphanie Breton[3], (1)Natural Resources Canada, Varennes, QC, Canada, (2)Natural Resources Canada, Varennes, Quebec, Canada, (3)CanmetENERGY/Natural Resources Canada, Varennes, QC, Canada*

3. Peak Electrical Demand Impacts of Air-Source Heat Pumps in Canadian Residential Buildings (TO-22-C042)
***Sarah Mollier**, Charles-Antoine Deslauriers, Justin Tamasauskas, P.Eng., Stéphanie Breton and Martin Kegel, P.Eng., CanmetENERGY/Natural Resources Canada, Varennes, QC, Canada*

4. Energy Use Sensitivity Analysis of Sensor Placement in Small Office Buildings with Dynamic Shading and Lighting (TO-22-A006)
***Hao Dong, Student Member**, Soham Vanage, Student Member and Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI*

11:00 AM - 12:30 PM

Conference Paper Session 4

Airflow and Ventilation Research

Track: Research Summit

Room: Osgoode (LC)
Chair: John Dunlap, Fellow Life Member, Dunlap & Partners, Richmond, VA
The COVID-19 pandemic is highlighted the importance of understanding and controlling how air moves through buildings. In this session, recent experimental and computational research studies are presented studying different aspects of airflow and ventilation in buildings, clean rooms and data centers.

Learning Objectives:

1. identify effects on indoor air quality of natural ventilation
2. understand relationship between natural ventilation procedure in ASHRAE 62.1 and ventilation rate procedure with regards to resulting indoor air quality
3. Understand how detailed CFD can be used to determine flow resistance characteristics for data-center-level CFD.
4. Explain how well-known empirical (handbook) correlations and manufacturer's test data may not be very accurate.

1. Designing to Reduce Infection Transmission: Influence of Aerosolization Procedures on Near Zone Particle Number and Transport (TO-22-A002)
Shamia Hoque, Ph.D., Associate Member[1], *Elizabeth Colmer, Affiliate*[1], *Nathan Ramanjulu*[1], *Phillip Moschella, Affiliate*[2], *Qian Wang, Affiliate*[1] *and Charles Bennett, Affiliate*[1], *(1)University of South Carolina, Columbia, SC, (2)Department of Emergency Medicine, Greenville, SC*

2. Numerical Assessment of Indoor Air Quality in Buildings Designed with ASHRAE Standard 62.1-2019 Natural Ventilation Procedure (TO-22-A003)
Jordan Clark, Ph.D., Member *and Troye Sas-Wright, Student Member, The Ohio State University, Columbus, OH*

3. Performance Approaches for Improving Airflow Parallelism in a Semiconductor Cleanroom (TO-22-A004)
Indra Permana, Student Member[1], *Fujen Wang, Ph.D., P.E., Fellow ASHRAE*[1], *Den Low Han Guan, P.Eng., Fellow ASHRAE*[2], *Citra Chaerasari, Student Member*[1] *and Kusnandar Kusnandar, Student Member*[1], *(1)National Chin-Yi University of Technology, Taichung, Taiwan, (2)EMS Design and Consultation Sdn Bhd, Malaysia, Kuala Lumpur, Malaysia*

4. Flow Resistance Characteristics for Data Center CFD (TO-22-C009)
James VanGilder, P.E., Member[1], *Mark Pang*[1], *Wei Tian, Ph.D., Associate Member*[1], *Beichao Hu, Student Member*[2], *Cheng-Xian (Charlie) Lin, Ph.D., Member*[2] *and Mark Seymour, P.E., Member*[3], *(1)Schneider Electric, Andover, MA, (2)Florida International University, Miami, FL, (3)Future Facilities, London, United Kingdom*

11:00 AM - 12:30 PM

Conference Paper Session 5

Cold Climate Design

Track: Cold Climate Building System Design, Operation and Resilience

Room: Sheraton C (LC)
Chair: Paul Torcellini, Ph.D., P.E., Fellow ASHRAE, National Renewable Energy Laboratory, Golden, CO
If buildings and HVAC systems in cold climates are to be resilient, function efficiently and provide acceptable levels of occupant comfort and indoor environmental quality, their designers must understand the challenges cold climates pose for buildings, equipment and systems and apply design strategies to address these challenges. The papers in this session highlight some of these challenges and their solutions.

Learning Objectives:

1. Explain the challenges related to indoor air quality in rural Alaskan homes.
2. Apply housing data collected in a rural Alaskan community to new and innovative housing projects across the circumpolar North.
3. spread awareness of challenges related to housing in rural Alaskan communities.
4. Integrate a heat pump hydronic heating system with a conventional heating system and select operating paramenters.
5. Assess the carbon reduction benefits from deploying a heat pump heating system.
6. Explain why moisture condensation in roofs of natatorium is an issue in cold climates.

7. Describe "self-drying" roofs in cold climates and the role of vapor retarder in the roof deck assembly.
8. describe how in this case study, appliance selection increased thermal energy demand intensity figures in an otherwise high-performing building.
9. explain how by opting for simpler plant systems, the thermal energy demand intensity targets were achieved and to describe the additional benefits.

1. Addressing the Housing Challenges of Rural Alaska: Air Flow and Indoor Air Quality Characteristics of Residential Buildings (TO-22-C010)
Maria L. Milan, Student Member[1], *Kristen Cetin, Ph.D., P.E., Member*[1], *Jessica Taylor*[2] *and Cristina Poleacovschi*[2], *(1)Michigan State University, East Lansing, MI, (2)Iowa State University, Ames, IA*

2. Air Source Chiller/Heat Pump in a Hybrid System for Cold Climate Heating, First Year's Experience (TO-22-C011)
Jason J. Burbank, P.E., Life Member[1], *Kevin Seaman*[2] *and Tiffany Abruzzo, Member*[3], *(1)University of Massachusetts/Amherst, Amherst, MA, (2)Seaman Engineering Corporation, Millbury, MA, (3)ClimaCool Corp., Oklahoma City, OK*

3. Hygrothermal Modelling of Moisture Accumulation in Composite Roof Decks in High Humidity Environments Such As Natatoriums in Cold Climates (TO-22-C013)
Gourish Sirdeshpande, Ph.D., Member*, Armstrong World Industries Inc., Lancaster, PA*

4. The Impacts of Process Loads on Achieving Thermal Energy Demand Intensity: A Case Study (TO-22-C073)
Veronica Ochoa, CEng, Member[1], *Hassan Bokhary, Member*[2] *and Mohammad Fakoor, Ph.D., Member*[3], *(1)Read Jones Christoffersen Ltd, Vancouver, BC, Canada, (2)RJC, Edmonton, AB, Canada, (3)RJC Engineers, Vancouver, BC, Canada*

11:00 AM - 12:30 PM

Seminar 7 (Advanced)

Artificial Intelligence for Environmental Modeling

Track: Research Summit
Room: Dominion North (2)
Sponsor: 4.10 Indoor Environmental Modeling
Chair: Wangda Zuo, Ph.D., Member, Pennsylvania State University, State College, PA
The artificial intelligence technique can be used for both indoor and outdoor environmental modeling. It can significantly reduce the simulation time with similar accuracy compared to the computational fluid dynamics model. This seminar introduces the applications of artificial intelligence for predicting microclimate, indoor air pollution, and near-occupant conditions.

Learning Objectives:

1. Explain ANN and how it works with CFD generated training data
2. Describe the main differences (positive and negative) between AI, CFD and wind tunnels when used for wind estimation in urban environments
3. Articulate the some of the cost benefits that are achievable from early-stage microclimate and wind studies and where ML/AI fits into the design cycle
4. Explain how the satellite-derived air quality data can be used with other data set to estimate the indoor air pollution levels
5. Understand ANN and how it works with CFD generated training data
6. Understand the uncertainty of ANN models
7. Explain ANN and how it works with CFD generated training data
8. Describe the usage of AI for indoor airflow prediction

1. Estimate Indoor Air Pollution Integration of Satellite-Derived Air Quality Data
Yang-Seon Kim, Ph.D., Member*, Wichita State University, Wichita, KS*

2. Using Machine Learning in Wind Estimation for Microclimate Studies: Benefits and Pitfalls
Goncalo Pedro, Ph.D.*, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

3. CFD-Trained Ann Model for Approximating Near-Occupant Condition in Real-Time Simulations
James Lo, Ph.D., Member*, Drexel University, Philadelphia, PA*

4. A Novel Physics-Informed Algorithm for Training AI Models to Predict Indoor Airflow
Wangda Zuo, Ph.D., Member*, Pennsylvania State University, State College, PA*

11:00 AM - 12:30 PM

Seminar 8 (Intermediate)

Introduction to ASHRAE Global Occupant Behavior Database

Track: Research Summit
Room: Dominion South (2)
Sponsor: MTG.OBB Occupant Behavior in Buildings
Chair: Bing Dong, Ph.D., Associate Member, Syracuse University, Syracuse, NY
People spend nearly 90% of their time in buildings. Recent research studies demonstrated that occupant behaviors have significant impact on the building performance in relation to indoor environment and energy use. With the support from ASHRAE, we have developed a global occupant behavior database that collects and stores field measured occupant data, including occupant schedules (presence and people counting) and occupant behaviors (interactions with devices, equipment and systems in buildings) from 17 countries around the world. This seminar aims to introduce this new ASHRAE Global Occupant Behavior Database, its data schema and example data sets.

Learning Objectives:

1. Describe occupant behavior in buildings
2. Explain various measurement techniques related with occupant behavior
3. Explain how occupant behavior impacts building energy consumption
4. Identify available data sets related with occupant behavior and building energy usages
5. Learn metadata of occupants
6. Learn how Brick schema can be extended to represent metadata of occupants.

1. ASHRAE Global Occupant Behavior Database: An Overview
***Bing Dong, Ph.D., Associate Member**, Syracuse University, Syracuse, NY*

2. Representing Occupant Data with the Extended Brick Schema
***Tianzhen Hong, Ph.D., Fellow ASHRAE**, Lawrence Berkeley National Laboratory, Berkeley, CA*

3. A Living Lab Approach to Studying Occupants in Office Buildings: Results and Lessons Learned
***Liam O'Brien, Ph.D., Associate Member**, Carleton University, Ottawa, ON, Canada*

4. Giving Occupant Behavior Data a Second Life
***Clinton Andrews, Ph.D., P.E., Member**, Rutgers University, New Brunswick, NJ*

11:00 AM - 12:30 PM

Seminar 9 (Basic)

Load Calculations for the ASHRAE Headquarters Building: The Transition to the Heat Balance Method

Track: Fundamentals and Applications
Room: Provincial (2)
Sponsor: 4.1 Load Calculation Data and Procedures
Chair: Glenn Friedman, P.E., Fellow ASHRAE, Taylor Engineers, Alameda, CA
Many mechanical design engineers calculate peak cooling and heating loads using traditional methods: Radiant Time Series, Transfer Functions, CLTD. A current trend is the transition to tools using the ASHRAE Heat Balance (HB) Method. To support this transition, this seminar explains key issues practitioners must be aware of for successful use of the HB method, including quality control review.

Learning Objectives:

1. Describe the evolution of ASHRAE's various loads calculation methods
2. Explain the technical nuances for ASHRAE's most recent and recommended method, the Heat Balance (HB) Method
3. Identify the most important and most influential model inputs required in order to achieve accurate results using the Heat Balance (HB) Method
4. Contextualize how the Heat Balance (HB) Method is used in practice using the ASHRAE Headquarters Building as an example
5. Understand the heat balance method of load calculations is the most current method defined by ASHRAE.
6. Know the Heat Balance method requires a spatially aware model of the building and its rooms.
7. Identify the most important and most influential model inputs required in order to achieve accurate results using the Heat Balance (HB) Method.

8. Contextualize how the Heat Balance (HB) Method is used in practice using the ASHRAE Headquarters building as an example.
9. Identify the most important & most influential model inputs required in order to achieve accurate results using the Heat Balance (HB) Method
10. Contextualize how the Heat Balance (HB) Method is used in practice using the ASHRAE Headquarters Building as an example
11. Understand the technical nuances for ASHRAE's most recent and recommended method, the Heat Balance (HB) Method

1. Setting the Stage: Learning Heat Balance Load Calculation Sensitivities
***Glenn Friedman, P.E., Fellow ASHRAE**, Taylor Engineers, Alameda, CA*

2. Key Heat Balance Application Considerations: Part 1
***James Pegues, Member**, Carrier Corporation, Syracuse, NY*

3. Key Heat Balance Application Considerations: Part 2
***Liam Buckley, CEng, BEMP, Member**, IES Ltd., Walnut Creek, CA*

11:00 AM - 12:30 PM

Seminar 10 (Basic)

Smart Buildings as a Transactive Energy Hub: Decarbonizing by Enhancing Building-to-Grid Interactions

Track: Connected Buildings, Connected Communities
Room: Grand East (LC)
Sponsor: 7.5 Smart Building Systems, 1.4 Control Theory and Application
Chair: Ron Bernstein, Member, RBCG Consulting, San Diego, CA
Decarbonization of the energy grid can get a boost from greater interactions and integration with building control system and their loads. Significant work over the last few years in this area has helped establish new requirements, standards and solutions. This session focuses on the key issues, current best practices, case studies and designing for interoperability, integration and interaction. Hear industry experts share about leading policy, regulation and pilot projects in California; the positive affects of building to grid integration; design and specification requirements; and how energy management information systems can facilitate buildings as a transactive energy integration hub.

Learning Objectives:

1. Explain how utility programs are supporting better building to grid interactions
2. List several approaches to the design and implementation of enhanced energy related building control and integration solutions
3. Define the key principals of building system interoperability, integration and interaction
4. Explain the grid benefits buildings can provide using transactive systems
5. Attendees will understand several approaches to the design and implementation of enhanced energy related building control and integration solutions.
6. Attendees will gain an understanding of the key principals of building system interoperability, integration, and interaction.
7. Attendees will gain an understanding of the key principals of building system interoperability, integration, and interaction
8. Attendees will understand several approaches to the design and implementation of enhanced energy related building control and integration solutions
9. Explain how utility programs are supporting better building to grid interactions
10. List several approaches to the design and implementation of enhanced energy related building control and integration solutions

1. Building to Grid Integration: Affects of Grid Load Balancing with Smart Building Integrations
***David Forfia**, DOE - Gridwise Architecture Council - GWAC, Washington, DC*

2. Automating Demand Management in Buildings
***Joe Zhou, Ph.D., P.E., Member**, Slipstream, Madison, WI*

3. Specifying Building to Grid Interactions, Interoperability and Integration: A Path to Decarbonization
***Ron Bernstein, Member**, RBCG Consulting, San Diego, CA*

4. Smart Buildings As a Transactive Energy Hub: Decarbonizing By Enhancing Building to Grid Interactions
***Agatha Kazdan**, Electric Power Research Institute (EPRI), Palo Alto, CA*

Sunday, June 26, 1:30 PM - 3:00 PM

Conference Paper Session 6

Building Load Research

Track: Research Summit

NY PDH G

Room: Osgoode (LC)

Chair: Nohad Boudani, PEng, Member, Sodicom, Beirut, Lebanon

The papers in this session explore recent research on a wide range of building load research topics including deployment of methods to provide building load flexibility via active insulation control and participation in flexibility services. Other research includes evaluation of the change in electrical load patterns due to the COVID-19 pandemic and new ways to predict building cooling loads.

Learning Objectives:

1. After attending this session, the attendees will be able to see benefits of combined optimization of HVAC and AIS controls compared to a case with optimized HVAC-only control.
2. After attending this session, the attendees will be able to compare and contrast two mechanisms for charging building thermal mass.
3. Does COVID-19 pandemic changed the way we use appliances?
4. Which appliance usage was affected the most during the pandemic?
5. Spatial and temporal features in building cooling load time series data
6. Applications of the proposed short-term building load prediction framework
7. Explain why building loads can be used as flexible loads in high renewable scenario's
8. Quantify the amount for demand flexibility that can be provided by HVAC cooling loads

1. Joint Optimization of HVAC and Active Insulation Control Strategies in Residential Buildings (TO-22-C014)
Gregory Pavlak, Ph.D., Member *and Amin Sepehri, Student Member, The Pennsylvania State University, University Park, PA*

2. Variations in Residential Building Electricity-Consuming Appliances Due to the COVID-19 Pandemic (TO-22-C015)
Debrudra Mitra*, Tara Younessi, Emily Kawka, Student Member and Kristen Cetin, Ph.D., P.E., Member, Michigan State University, East Lansing, MI*

3. A Novel Framework for Building Cooling Load Prediction Exploring the Spatial and Temporal Dependencies Using an Ensemble Approach (TO-22-A005)
Akshay Jindal, Member*, Juan-Carlos Baltazar, Ph.D., BEMP, Member and David Claridge, Ph.D., P.E., Fellow ASHRAE, Texas A&M University, College Station, TX*

4. Estimating Demand Flexibility Using Cooling Loads in Commercial Office Buildings (TO-22-A007)
Soham Vanage, Student Member[1]*, Kristen Cetin, Ph.D., P.E., Member*[1]*, James McCalley, Ph.D.*[2] *and Yu Wang, Ph.D.*[2]*, (1)Michigan State University, East Lansing, MI, (2)Iowa State University, Ames, IA*

1:30 PM - 3:00 PM

Conference Paper Session 7

Sensors and Airflow Controls: Making Buildings Smarter through Data and Controls

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings

G

Room: Sheraton C (LC)

Chair: Constantinos A. Balaras, Ph.D., Fellow ASHRAE, Institute for Environmental Research & Sustainable Development, NOA, Athens, Greece

As buildings and their systems increasingly are instrumented with sensing technologies and controls, there is a substantial opportunity to, as a result, make buildings smarter by using this data to improve the IAQ, comfort, and/or energy use of the building. This session covers efforts to use sensors and controls to improve building operations.

Learning Objectives:

1. Understand the definitions of containment ratio and barrier effectiveness
2. Describe a test to determine barrier effectiveness
3. Explain why space pressurization is key for preventing airborne transmission of pathogens.
4. Describe some ways to achieve efficient space pressurization
5. Learn a case of saving cooling energy in factory buildings by performing artificial neural network-based MPC.

6. Learn the indoor environment characteristics according to the spatial characteristics and operational characteristics of the factory building.
7. Understand the concept of sensor threshold marginal cost for fault detection and diagnostics purpose
8. Learn the key cost considerations in sensor selection for cost-effective fault detection and diagnostics.

1. A Field-Testing Protocol for Containment Testing of Rooms Using Simple $PM_{2.5}$ Meters (TO-22-C016)
Edward Renshaw, Member[1] *and Travis English, P.E., Member*[2]*, (1)Kaiser Permanente, Oakland, CA, (2)Kaiser Permanente, Anaheim, CA*

2. Improved Pressure and Airflow Control in Pressure Controlled Spaces with Low Leakage Ceiling Panels (TO-22-C017)
Gourish Sirdeshpande, Ph.D., Member *and William H Frantz, Member, Armstrong World Industries Inc., Lancaster, PA*

3. Real-Time Implementation of Model Predictive Control for Cooling System of a Factory Building (TO-22-C019)
Seon-Jung Ra[1]*, Jin-Hong Kim*[1]*, Cheol-Soo Park, Ph.D.*[2]*, Hyeong-Gon Jo*[1] *and Young-Sub Kim*[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)*

4. Sensor Cost Analysis for Sensor Impact Evaluation in Data-Driven Fault Detection and Diagnostics (TO-22-C020)
Liang Zhang, Ph.D., Member *and Matt Leach, National Renewable Energy Laboratory, Golden, CO*

1:30 PM - 3:00 PM

Seminar 11 (Intermediate)

Applying UV as Best Practices and Pandemic Preparedness to Address Air and Surfaces Disinfection within Buildings

Track: Buildings in the Aftermath of COVID-19
Room: Dominion North (2)
Sponsor: 2.9 Ultraviolet Air and Surface Treatment
Chair: Aaron Engel, Member, Fresh-Aire UV, Jupiter, FL
UV disinfection played an important role as part of a layered strategy for addressing airborne and surface contamination during the COVID-19 pandemic. Applying UV disinfection to air and surfaces within the HVAC system, duct work, and occupied spaces should not only be reserved for pandemic preparedness but also a best practices strategy for improved sanitized spaces and better IAQ for building occupants. This seminar discusses various applications using UV disinfection, such as upper air, surface, airstream, HVAC as well as the different types of UV wavelengths being applied to achieve a healthier building.

Learning Objectives:

1. Apply the right UV strategy for specific applications.
2. Distinguish between HVAC coil mount and airstream duct mount UV disinfection.
3. Understand the safety protocols needed to safely operate a UV disinfection system.
4. Explain the difference methods for applying UV in occupied and unoccupied spaces.
5. The application of upper room UVC systems to control the transmission of airborne diseases
6. The application of whole room UVC systems to control surface borne organisms that can transmit disease

1. Applying UV Disinfection Technologies to in Room and Occupied Spaces
Richard Vincent, Member*, Icahn School of Medicine at Mount Sinai, New York, NY*

2. Applying UV Disinfection Technologies for Unoccupied Spaces
David Skelton, Member*, EvergreenUV, Memphis, TN*

3. UV Disinfection for HVAC and Duct Mount
Aaron Engel, Member*, Fresh-Aire UV, Jupiter, FL*

1:30 PM - 3:00 PM

Seminar 12 (Intermediate)

Building Envelopes as Distributed Energy Systems

Track: Research Summit
Room: Dominion South (2)
Sponsor: 4.4 Building Materials and Building Envelope Performance
Chair: Florian Antretter, Member, Fraunhofer IBP, Holzkirchen, Germany
Traditional building envelopes have passive insulation systems that cannot respond and make use of the dynamic changes in the environment. Phase change material (PCM) integration into building envelopes is a recognized and well-established technique for

thermal load management in buildings. Adding thermal storage to building envelopes and controlling the charge and discharge can enable substantial reduction in heating and cooling loads during peak hours. This seminar revisits concepts and challenges to utilize building envelopes as distributed energy systems and provides load flexibility and fast thermal energy management for the smart grid.

Learning Objectives:

1. Describe concepts of active insulation systems and their energy savings potential and challenges of their application
2. Describe benefits and limitations of PCMs for their utilization in buildings
3. Explain thermal load management in buildings using PCMs
4. Identify passive thermal management solutions in Data Centers, Telecom shelters, and buildings
5. Describe concepts of active insulation systems and their energy savings potential and challenges of their application
6. Describe benefits and limitations of PCMs for their utilization in buildings
7. Provide an overview of concepts of active insulation systems and their energy savings potential
8. Describe the challenges and needs in applying active insulation systems in actual buildings

1. Impacts of Variable Thermal Conductivity and Surface Heat Transfer on PCM Performance in Envelopes
***Paulo Cesar Tabares-Velasco, Ph.D., Associate Member**, Colorado School of Mines, Golden, CO*

2. Challenges and Opportunities of Active Insulation Systems: How Can We Achieve Our Energy and Cost-Saving Targets?
***Mikael Salonvaara, Member**, Oak Ridge National Laboratory, Oak Ridge, TN*

3. Energy Savings and Load Flexibility Potential of PCM-Integrated Building Envelopes
***Ravi Kishore, Ph.D.**, National Renewable Energy Laboratory, Golden, CO*

4. Energy Conservation Measures and Thermal Management Solutions in Technical Spaces
***Jason Baker** and Rami Saeed, Idaho National Laboratory, Idaho Falls, ID*

1:30 PM - 3:00 PM

Seminar 13 (Intermediate)

Recent Advances in Data Center CFD Simulation

Track: Research Summit
Room: Provincial (2)
Sponsor: 4.10 Indoor Environmental Modeling, 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment
Chair: Yang-Seon Kim, Ph.D., Member, Wichita State University, Wichita, KS
Modeling data center airflow patterns and temperature distributions with CFD has been a time-consuming process. With the proliferation of data centers and their enormous power consumption, it is critical that the technology be made more integral to data center design and management. Fortunately, recent advances have made data center CFD faster and more accurate. The recent ASHRAE Research Project RP-1675, Guidance for CFD Modeling of Data Centers, has delivered best-practice modeling techniques to the data center community. This seminar presents recent advances in the areas of hardware, CFD algorithms, and equipment-modeling techniques and illustrates their use by way of examples.

Learning Objectives:

1. Explain how parallelization can dramatically speed-up CFD simulations
2. Explain why external flow analysis requires good engineering judgement to interpret the results
3. Explain the importance of pressure drop across perforated tiles in a full featured data center
4. Describe how to model a perforated tile when a raised-floor plenum is included in a CFD model
5. Explain how parallelization can dramatically speed-up CFD simulations.
6. Describe the primary benefit of compact CFD models over explicit representations.

1. Fast and Accurate CFD for Data Center Applications
***James W. VanGilder, P.E., Member**, Schneider Electric, Andover, MA*

2. Cutting Edge or Practical? Simulating External Airflow for Data Centers
***Mark Seymour, P.E., Member**, Future Facilities, London, United Kingdom*

3. The Importance of Managing Pressures Losses in Data Centers
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

4. Perforated Tile CFD Modeling in a Full Featured Data Center: Lessons Learned in RP-1675
***Cheng-Xian Lin, Ph.D., Member**, Florida International University, Miami, FL*

1:30 PM - 3:00 PM

Seminar 14 (Intermediate)

The Importance of O&M to Energy Efficiency, Comfort, IAQ and Energy System Decarbonization

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: 7.3 Operation, Maintenance and Cost Management, 7.5 Smart Building Systems, TC 7.6
Chair: Michael Brambley, Ph.D., Fellow Life Member, Pacific Northwest National Laboratory, Richland, WA
The earth is warming from emissions of greenhouse gases into the atmosphere with disastrous potential human impacts in this century. Signs are already evident: increasing major storm frequency, melting glaciers and super droughts. Building O&M are often overlooked in this context. Effective O&M is essential to ensure sustainable buildings remain so, and O&M improvements across the large existing buildings sector could cut GHG emissions quickly while improving energy efficiency, comfort and IAQ. The seminar explores ways of improving building O&M and the potential impacts of improved O&M on GHG emissions, energy efficiency and comfort.

Learning Objectives:

1. Understand and adapt some of the evolving best practices for introducing concepts such as IAQ and decarbonization into a small facility.
2. Describe the major technology presently at the forefront of electrification of heating in the Northeast and upper Midwest.
3. Explain why communication and rapid resolution of HVAC hardware and building automation system problems are vital to keeping points out of "operator" mode.
4. Maintain operations and maintenance documentation with the purpose of improving building comfort, IAQ, and energy efficiency.
5. Understand that the best-designed facilities cannot achieve their design-level performance unless they are properly controlled
6. Address human factors challenges presented by BAS technicians, operators, and tenants, and draw upon methods to address them in order to achieve stable and efficient building system performance that satisfies all stakeholders
7. Develop Training Material with the focus on energy efficiency and decarbonization for the long term.
8. Understand how an un-commissioned or poorly commissioned buildings are unlikely to meet energy goals.
9. Maintain operations and maintenance documentation with the purpose of improving building comfort, IAQ, and energy efficiency.

1. Best Practices for Building Operations and Maintenance: Where Small Building Performance Meets IAQ and Decarbonization
***Sonya Pouncy, Member**, Building Vitals, Detroit, MI*
2. Changing O&M Under De-Carbonization Scenarios
***Michael Bobker, Member**, CUNY Institute for Urban Systems, New York, NY*
3. Tuning the BAS: Stabilizing Performance to Improve Energy Efficiency
***Orvil Dillenbeck, P.Eng., Member**, Canadian Nuclear Laboratories, Chalk River, ON, Canada*
4. Commissioning and Training: Setting the Foundation for Success
***Michael Flemming, P.E., Associate Member**, Interface Engineering, San Francisco, CA*

Sunday, June 26, 3:15 PM - 4:45 PM

Seminar 15 (Basic)

LIVESTREAM: Update on the Progress of the Task Force for Building Decarbonization

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: Task Force for Building Decarbonization
Chair: Don Brandt, Member, ASHRAE Design ESSENTIALS Instructor, Atlanta, GA
Update ASHRAE members and industry associates on the progress of the task force on building decarbonization through June of 2022 and project future products.

Learning Objectives:

1. Explain the Decarb process
2. Describe the Decarb Position document

3. Identify the Decarb BPS
4. Identify the 3 types of carbon
5. Explain the background and history of the Task Force for Building Decarbonization
6. Describe the progress of the Task Force's original objectives and a list of available deliverables from the Task Force
7. Describe the new ASHRAE Position Document on Building Decarbonization
8. Describe the upcoming new, restructured Task Force for Building Decarbonization

1. Update Session 1
***Thomas Phoenix, P.E., BEMP, Presidential Fellow ASHRAE**, Mechanical Contractors, Inc, Charlotte, NC*
2. Update Session 2
***Donald Colliver, Ph.D., P.E., Presidential Member**, University of Kentucky, Lexington, KY*

Monday, June 27

Monday, June 27, 8:00 AM - 9:30 AM
Debate 1 (Intermediate)

College of Fellows Debate "Be Like Water:" Engineers Have a Duty to Address Climate Change Adaptation and Resilience

Track: Professional Development and Education
Room: Sheraton C (LC)
Sponsor: 1.7 Business, Management & General Legal Education, 7.1 Integrated Building Design, 2.8 Building Environmental Impacts and Sustainability
Chair: Larry Spielvogel, P.E., Fellow Life Member, Consulting Engineer, Bala Cynwyd, PA, Mitchell Swann, P.E., Resolution Management Consultants, Marlton, NJ, Mina Agarabi, P.E., Member, Agarabi Engineering PLLC, New York, NY, David Shipley, P.Eng., Member, Posterity Group, Ottawa, ON, Canada and Kelley Cramm, P.E., Member, Henderson Engineers, Lenexa, KS
While the COVID pandemic has certainly been the biggest red blob on the world's radar screen, the impacts of out-of-the-norm weather events has been a strong second. Droughts, floods, wild fires and heat waves have whipsawed many around the globe. What's an engineer to do? What is an engineer obligated to do? How much is too much? How much is not enough? The College has visited related subjects before, but the intensity and interest has grown, especially in the push for decarbonization and resiliency. The College goes live and engages these livewire topics in this lively debate.

8:00 AM - 9:30 AM
Conference Paper Session 8

Refrigerants and HX Research

Track: Research Summit
G
Room: Osgoode (LC)
Chair: Ahmed Elatar, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN
The deployment of new, lower global warming potential and highly efficient heat transfer equipment are critical for meeting legislative targets and developing more energy efficient equipment. This session includes relevant research on chemical stability and system performance of new, lower global warming potential refrigerants, and methods to understand performance of brazed plate heat exchangers.

Learning Objectives:

1. Explain the highly accelerated life testing (HALT)conditions and materials used during the AHRTI 9016 investigation with refrigerants R-1336mzz(Z), R-1336mzz(E), R-514A, R-1233zd(E), and R-1224yd(Z) with Lubricants
2. Provide insights into AHRTI 9016 chemical stability investigations with R-1336mzz(Z), R-1336mzz(E), R-514A, R-1233zd(E), and R-1224yd(Z) with Lubricants
3. quantify the potential CO2 saving from replacing R134a with R1234yf
4. Spot points for further modification to improve the R1234yf LCCP analysis
5. Describe how "smart control" works to improve efficiency of heat exchanger system.
6. Provide an overview of testing heat exchanger testing in industry.

1. Chemical Stability of Low-Pressure Refrigerants with Lubricants (TO-22-C021)
Stephen Kujak, Member[1], *Elyse Sorenson, Member*[1], *Xudong Wang, Ph.D., Member*[2], *Morgan Leehey, Associate Member*[1], *Cameron Robaczewski*[1] *and Trever Stellpflug*[1], *(1)Trane Technologies, La Crosse, WI, (2)Air-Conditioning, Heating and Refrigeration Technology Institute, Arlington, VA*

2. LCCP Assessment of R1234yf as a Low GWP Alternative for R134a in Domestic Refrigerators (TO-22-C022)
Mohamed Ragab Khaled Zain, *Asmaa Elsayed, Mohamed El Morsi and Omar Abdelaziz, Ph.D., Member, The American University in Cairo, Cairo, Egypt*

3. Method for Brazed Plate Heat Exchanger Heat Load Estimation: Analytical Approach and Experimental Verification (TO-22-A008)
Chen Feng, Ph.D.[1], *Redmond Hum*[2], *Marcelo Acosta, P.E., Member*[2] *and Sanjeev Chandra, Ph.D.*[1], *(1)University of Toronto, Toronto, ON, Canada, (2)Armstrong Fluid Technology, Toronto, ON, Canada*

8:00 AM - 9:30 AM

Seminar 16 (Intermediate)

Case Studies of Heat Reclaim from Refrigeration Applications

Track: Fundamentals and Applications
Room: Dominion North (2)
Chair: Richard Love, Associate Member, Massey University, Palmerston, New Zealand

Heat reclaim from refrigeration systems can be a cost effective and sustainable method of providing simultaneous heating and refrigeration. It can also aid in decarbonisation by replacing fuel-based heating systems with electrically powered refrigeration and heat pump systems. This seminar examines current and historical case studies including successes and failures, and what improvements could be made.

Learning Objectives:

1. Describe different methods by which heat reclaim / heat recovery can be implemented with refrigeration and heat pump systems.
2. Explain how heat reclaim can improve the sustainability of a site and aid decarbonization goals.
3. Identify opportunities for heat reclaim given the refrigeration and heating demand at a site.
4. Identify and mitigate situations and configurations that may imped successful heat reclaim applications.
5. Describe different methods by which heat reclaim / heat recovery can be implemented with refrigeration and heat pump systems.
6. Explain how heat reclaim can improve the sustainability of a site and aid decarbonization goals
7. Understand at what temperature most refrigeration system offer the majority of waste heat recovery
8. Understand, When R-744 (Carbon Dioxide) operates in the transcritical region more heat is available at a higher grade than with other refrigerants.
9. Understand, What grades of heat are typically available from a refrigeration system.
10. Identify, Which locations can utilize low and high grade heat in a building
11. Understand the importance of equipment installation is essential
12. Explain the importance of heat recovery load balancing
13. Explain the importance of commissioning

1. Decarbonizing Supermarkets
Tom Wolgamot, P.E., CPMP, Member, *DC Engineering, Missoula, MT*

2. Reducing CO2 Emissions through Effective Utilization of Refrigeration System Heat Recovery
Jonathan Berney, P.Eng., *CIMCO Refrigeration, Toronto, ON, Canada*

3. Heat Recovery Success and Some That Are Not!
John Scott, Member, *Natural Resources Canada, Varennes, QC, Canada*

8:00 AM - 9:30 AM

Seminar 17 (Intermediate)

How to Select and Size HVAC Fans for Optimum Acoustical Performance

Track: HVAC&R Systems and Equipment
Room: Dominion South (2)
Sponsor: 2.6 Sound and Vibration, 5.1 Fans
Chair: E. Curtis Eichelberger, P.E., Fellow ASHRAE, Eichelberger Acoustics LLC, Harrisburg, PA

This seminar provides basic information on how fans are measured for sound, why different fan types generate different sound levels, and why two fans with the same sound level but different fan design can sound totally different and yield very different sound levels in remote locations. Guidance is provided as to how to best select the appropriate fan type and size for a given application. Finally, case studies are presented illustrating real situations where a poor fan selection has resulted or could have resulted in a noise problem that was difficult and/or expensive to resolve.

Learning Objectives:

1. Explain how to avoid selecting a noisy fan for a given application
2. Describe how the source path receiver model is used to estimate noise levels for occupied spaces
3. Specify the correct industry standard for a given type of air moving equipment
4. List options for fan noise mitigation
5. Understand how to avoid selecting a noisy fan for a given application.
6. Understand how the source path receiver model is used to estimate noise levels for occupied spaces.
7. Be able to specify the correct industry standard for a given type of air moving equipment.
8. List options for fan noise mitigation.

1. Basics of Fan Noise and Application Considerations
***Rad Ganesh, Ph.D., P.E., Member**, Twin City Fan Companies Ltd, Rogers, MN*

2. Fan Noise in Air Handling Systems
***Paul Bauch, Member**, Johnson Controls, York, PA*

3. 20/20 Foresight: Choosing the Right Fan for the Job (Case Studies)
***Jerry Lilly, P.E., Member**, 5266 NW Village Park Drive, Issaquah, WA*

8:00 AM - 9:30 AM

Seminar 18 (Intermediate)

Impacts on Occupants' Experience in Grid-Interactive Efficient Building Operations

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Provincial (2)
Sponsor: 7.5 Smart Building Systems, MTG.OBB Occupant Behavior in Buildings
Chair: Li Song, Ph.D., P.E., Member, University of Oklahoma, Norman, OK
Grid-interactive efficient building (GEB) operation promises a viable means to offset increases in variability of the power grid associated with increasing deployment of variable renewable generation on the grid, resulting in a change in paradigm for managing electric system operations in buildings. Providing grid service while meeting the occupants' needs, GEB operation will unavoidably have impacts on occupants' experience in the built environment. This seminar includes several recent studies on energy performance and occupant experiences associated with the impacts of GEB operations. The studies include test and analysis results for residential buildings, commercial buildings and an urban-scale occupant-centric ecosystem.

Learning Objectives:

1. Explain how existing legacy air conditioners and heat pumps can be set up to provide peak electric demand reductions under time-of-use prices for electricity
2. Explain the tradeoffs between user's experience and energy performance in smart home operations
3. Explain how traditional comfort zone approaches to modeling occupant behavior fall short when used to model occupant overrides in demand response programs
4. Understand how occupant behavior impacts building operations while considering grid needs and flexibility
5. Understand thermal compromise for cost saving only optimal operation
6. How to use the thermal comfort index to regulate the state, instead of decision
7. Understand the factors affect the cost saving / thermal comfort in a smart home

1. Homes in Control: Ensuring Comfort and Cost Savings While Providing Peak Demand Reductions to the Power Grid
***Michael Brambley, Ph.D., Fellow Life Member**, Pacific Northwest National Laboratory, Richland, WA*

2. Understanding the Correlations between Cost Savings and Occupants' Comfort and Convenience for Grid-Interactive Smart Home Operation
***Yilin Jiang, Student Member**, University of Oklahoma, Norman, OK*

3. Thermostats out of Control: Understanding the Automation, Occupancy, Habits and Frustrations that Drive Setpoint Changes
***Michael Kane, Ph.D., Member**, Northeastern University, Boston, MA*

4. Occupant-Centric Ecosystem: From Smart Buildings to Smart Cities

***Bing Dong, Ph.D., Associate Member**, Syracuse University, Syracuse, NY*

8:00 AM - 9:30 AM

Seminar 19 (Intermediate)

Understanding and Analysis of Inter-Building Effects to Inform Decision Making on Urban Buildings

Track: Connected Buildings, Connected Communities
Room: Grand East (LC)
Sponsor: 4.7 Energy Calculations
Chair: Tianzhen Hong, Ph.D., Fellow ASHRAE, Lawrence Berkeley National Laboratory, Berkeley, CA
Buildings located in an urban area influence each other: (1) solar radiation affected by shading from nearby buildings, (2) solar reflection and absorption, (3) longwave radiant heat exchange. In addition, these buildings release heat to the surrounding environment and change the local microclimate (ambient air temperature and humidity) which in turn influences building energy demand. Nearby buildings may be served by a district energy system to meet their aggregated demands. This seminar presents and analyzes these inter-building effects which are essential to consider when designing or retrofitting a district of urban buildings for performance improvements.

Learning Objectives:

1. Describe inter-building effects
2. Explain under what context the inter-building effects need to be considered
3. Identify methods (physics-based modeling and data-driven approaches) to quantify inter-building effects
4. Describe urban sensing technologies that provide measured data to help quantify inter-building effects
5. Describe reinforcement learning
6. Understand potential interactions in connected communities
7. Understand what are inter-building effects and under what context the inter-building effects need to be considered.
8. Learn methods (physics-based modeling and data-driven approaches) to quantify inter-building effects.
9. Describe inter-building impacts using a graph structure
10. Apply graph-based data-driven methods to predict building energy use under inter-building impacts

1. Monitoring Inter-Building Conditions by Means of Human-Centric Techniques for Investigating Indoor-Outdoor Microclimate and Building Energy Needs
***Anna Laura Pisello, Ph.D.**, University of Perugia, Perugia, Italy*

2. Citylearn: Multi-Agent Demand Response for Connected Communities
***Zoltan Nagy, Ph.D., Associate Member**, The University of Texas at Austin, Austin, TX*

3. Modeling Urban Building Interactions Using EnergyPlus
***Tianzhen Hong, Ph.D., Fellow ASHRAE**, Lawrence Berkeley National Laboratory, Berkeley, CA*

4. A Graph-Based Hybrid Approach Towards Building Energy Prediction in an Urban Context By Integrating Inter-Building Impacts
***Yuqing Hu, Ph.D.**, Penn State University, State College, PA*

Monday, June 27, 9:45 AM - 10:45 AM

Poster 9 (Intermediate)

Occupant Behavior and Smart Buildings (Posters)

Track: Connected Buildings, Connected Communities
Room: Osgoode (LC)
Chair: Brian Fronk, Ph.D., Member, Oregon State University, Corvalis, OR
Poster Sessions begin with each author giving a brief oral overview of their paper, then going to their poster stations to respond to any questions attendees may have regarding the work reported on. The papers in this session report on a range of building automation concepts including IoT, fault detection and diagnosis, commissioning, smart thermostats, etc.

Learning Objectives:

1. Elaborate tradeoffs between microgrid versus energy efficiency costs.
2. initiate similar analyses where building energy modeling and microgrid analysis are intermixed
3. Describe how the IoT-based fault detection approach works
4. Appreciate the significance/benefit of fault detection for residential HVAC

5. Describe what is EOC and why we care about it
6. Apply EOC method to evaluate the ease of commissioning of different occupancy sensor systems
7. describe the hardware-in-the-loop approach for generating load flexibility data in commercial buildings.
8. understand challenges in hardware-in-the-loop integration, such as: 1) how to design the overall data infrastructure to ensure effective, robust, and efficient integration; 2) how to avoid closed-loop hunting between simulated and emulated variables; 3) how to quantify system response times and minimize system delays; and 4) how to assess the overall integration quality.
9. Understand the hardware in the loop (HIL) framework of the Water Source Heat Pump HIL testbed.
10. Understand the testing capability of the Water Source Heat Pump HIL testbed.
11. Learn what are the environmental parameters correlated with adjustment behaviors of smart thermostats, in high-rise residential buildings.
12. Realize how Bayesian inference is used in training of a mixture of logistic regression models, including how to let models automatically determine the number of clusters and split day of the year into seasons.
13. Describe Canada's small commercial building demographics.
14. Describe data availability and limitations with smart thermostat control upgrades.
15. Describe the smart home research capabilities that Texas A&M Smart Home Lab testbed has to offer.
16. Provide an overview of the areas of research that can be conducted inside the Texas A&M Smart Home Lab testbed.
17. Apply a methodology for optimizing the operation of both thermal and non-thermal appliance in a connected home.
18. Understand a data-driven home thermal model for the HVAC system and its parameter estimation procedure.

1. Low-Cost Community Micro-Grids By Efficiency and Reduced Availability (TO-22-C074)
Daniel Villa, P.E., Member[1]*, Jimmy Quiroz, P.E.*[2]*, Jack D. Flicker, Ph.D.*[2]*, C. Birk Jones, Ph.D.*[2] *and Frances Pavich*[3]*, (1)Sandia National Laboratories, Alamo (virtual employee), TX, (2)Sandia National Laboratories, Albuquerque, NM, (3)Transcendence LLC, Santa Fe, NM*

2. An IoT-Based Approach for Automated Fault Detection and Diagnosis in Residential HVAC systems (TO-22-C025)
Kevwe Ejenakevwe*, Junke Wang, Student Member and Li Song, Ph.D., P.E., Member, University of Oklahoma, Norman, OK*

3. Development and Evaluation of Ease of Commissioning of HVAC-Connected Occupancy Sensor Systems in Buildings (TO-22-C026)
Kristen Cetin, Ph.D., P.E., Member*, Yiyi Chu, Debrudra Mitra and Nizar Lajnef, Michigan State University, East Lansing, MI*

4. Development of a Hardware-in-the-Loop Testbed for Laboratory Performance Verification of Flexible Building Equipment in Typical Commercial Buildings (TO-22-C027)
Jin Wen, Ph.D., Member[1]*, Zhelun Chen, Ph.D., Associate Member*[1]*, Steven Bushby, Fellow ASHRAE*[2]*, Caleb Calfa*[3]*, Yangyang Fu, Ph.D., Member*[3]*, Gabriel Grajewski*[1]*, Yicheng Li*[1]*, L. James Lo, Ph.D., Member*[1]*, Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE*[3]*, W. Vance Payne, Ph.D., Member*[2]*, Amanda Pertzborn, Ph.D., Associate Member*[2] *and Zhiyao Yang, Ph.D., Member*[3]*, (1)Drexel University, Philadelphia, PA, (2)NIST, Gaithersburg, MD, (3)Texas A&M University, College Station, TX*

5. Development of a Water Source Heat Pump Hardware-in-the-Loop (HIL) Testing Facility for Smart Building Applications (TO-22-C028)
Caleb Calfa[1]*, Zhiyao Yang, Ph.D., Member*[1]*, Yangyang Fu, Ph.D., Member*[2]*, Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE*[1]*, Jin Wen, Ph.D., Member*[2] *and Zhelun Chen, Ph.D., Associate Member*[2]*, (1)Texas A&M University, College Station, TX, (2)Drexel University, Philadelphia, PA*

6. Discovering Potential Driving Factors of Hold Behaviours of Smart Thermostat Using Logistic Regression and Clustering (TO-22-C029)
Yufeng Deng*, Seungjae Lee, Ph.D., Associate Member and Marianne Touchie, Ph.D., P.E., Associate Member, University of Toronto, Toronto, ON, Canada*

7. Occupant Behaviour and Thermal Comfort in Small Commercial Buildings: A Longitudinal Study Using Smart Thermostat Data (TO-22-C030)
Brent Huchuk, Ph.D., Associate Member[1]*, Farid Bahiraei, Ph.D.*[1]*, Saptak Dutta*[1]*, Jared Goodman*[2]*, Rajendran Avadaiappan*[2] *and Andre Roman*[2]*, (1)National Research Council Canada, Ottawa, ON, Canada, (2)Energy Metrics LLC, New York, NY*

8. Smart and Connected Home Testbed (TO-22-C031)
Thomas Firsich, Student Member*, Zhiyao Yang, Ph.D., Member, Fan Feng, Student Member and Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE, Texas A&M University, College Station, TX*

9. Connected Home Energy Management for Grid-Interactive Operations: Consider Coupling Effect Among Appliances (TO-22-C075)
Yilin Jiang, Student Member *and Li Song, Ph.D., P.E., Member, University of Oklahoma, Norman, OK*

9:45 AM - 10:45 AM

Seminar 20 (Intermediate)

LIVESTREAM: Cybersecurity, Securing Building Control Systems: Are We Meeting Industry's Needs?

Track: HVAC&R Systems and Equipment
Room: Grand East (LC)
Sponsor: 1.4 Control Theory and Application, 7.5 Smart Building Systems
Chair: Ron Bernstein, Member, RBCG Consulting, San Diego, CA
You can't turn on the news today without hearing about a new cybersecurity incident, but are our buildings a concern? Are HVAC control systems vulnerable? Should we be doing more to address the risks? This session explores the cybersecurity issues facing building controls today and discuss how owners, users, and suppliers are addressing current market needs. We'll hear from a technology expert, a major end user, and a consulting engineer on how they are approaching this highly critical topic. Participants are given an overview of ASHRAE's efforts to enhance building specifications and standards for cybersecurity.

Learning Objectives:

1. Describe the strategies for ensuring cyber risk is reduced through risk management and mitigation
2. Recognize the security risks to Facility Related Control Systems and ways to mitigate them
3. Describe prescriptive and performance-based topics in Cybersecurity specifications
4. Identify standards, guidelines, and resources available to help with Cybersecurity specifications and system requirements

1. Specifying Cybersecurity for HVAC Controls
***Terry Schroeder, P.E., HBDP, Member**, Whitman, Requardt & Associates, LLP, Baltimore, MD*

2. Enabling Reliability in the Built Environment by Promoting Cybersecurity of Building Control Systems: An Overview of What the Department of Defense Has Done to Strengthen Its Cybersecurity Posture within the Facility Environment
***Daniel Shephard, Member**, US Army Corps of Engineers, Champaign, IL*

3. Cybersecurity Baselines: From NIST to Industry Standards to Conformity Assessment
***Mike Bergman**, Consumer Technology Association, Arlington, VA*

9:45 AM - 10:45 AM

Seminar 21 (Intermediate)

Designing for Air Source Heat Pumps in Cold Climates

Track: Cold Climate Building System Design, Operation and Resilience
Room: Dominion South (2)
Sponsor: 9.6 Healthcare Facilities
Chair: Davide Ziviani, Ph.D., Member, Center for High Performance Buildings, Purdue University, West Lafayette, IN
This presentation deals with lessons learned from a recent Ontario healthcare project, which introduced hydronic Air Source Heat Pumps (ASHPs) to help transform an existing office building into a minor procedures centre. When considering overall seasonal efficiency, ASHPs present a much stronger case than traditional electric systems. However, they cannot perform reliably on a design day. Pulling from operation data from of a full calendar year, we will explore the possibilities and challenges associated with this implementation, as well as other uncommon new strategies that support energy efficiency.

Learning Objectives:

1. Describe decarbonization strategies for your building
2. Describe design and operational awareness related to the implementation of an Air Source Heat Pump (ASHP) system in a cold climate
3. Display confidence in deploying solutions to possible challenges associated with alternative solutions
4. Explain the importance of facilities maintenance staff being trained in new technology
5. Describe decarbonization strategies for your building.
6. Describe design and operational awareness related to the implementation of an Air Source Heat Pump (ASHP) system in a cold climate.
7. Display confidence in deploying solutions to possible challenges associated with alternative solutions.
8. Explain the importance of facilities maintenance staff being trained in new technology.

1. Designing for Air Source Heat Pumps in a Cold Climate
***Kurt Monteiro, P.Eng., HBDP and HFDP, Member**, Smith and Andersen Consulting Engineering, Toronto, ON, Canada*

2. Cold Climates: Designing for Air Source Heat Pumps
***Will Rea, P.Eng., Member**, HTS Engineering, Toronto, ON, Canada*

9:45 AM - 10:45 AM

Seminar 22 (Basic)

From Rendering to Reality: Teaching Young Engineers to Design for Construction

Track: Professional Development and Education
Room: Provincial (2)
Sponsor: 7.2 HVAC&R Construction & Design Build Technologies, Young Engineers in ASHRAE
Chair: Heather Schopplein-Anderson, P.E., Member, University Mechanical & Engineering Contractors, El Cajon, CA
Many young engineers enter the HVAC industry with little experience physically building their designs. They fail to realize that what fits in a 3D model doesn't necessarily work in reality once you add in hangers, equipment clearances, and construction tolerance. This seminar provides lessons learned from a young engineer and suggestions on methods to teach young engineers and more experienced engineers who are entering the design build field, how to design for construction.

Learning Objectives:

1. Provide an overview of the differences between design-build and design-bid-build project delivery methods
2. Describe the importance of relationships and communication between engineers and installers for constructible design and proper execution
3. Describe personal and professional development models to successfully onboard young engineers into the design-build process
4. Apply the strengths of the design-build delivery method to a traditional design-bid-build environment
5. Provide an overview of the differences between design-build and design-bid-build project delivery methods
6. Understand the importance of relationships and communication between engineers and installers for constructible design and proper execution
7. Propose personal and professional development models to successfully onboard young engineers into the design-build process
8. Apply the strengths of the design-build delivery method to a traditional design-bid-build environment
9. Understand the importance of relationships and communication between engineers and installers for constructible design and proper execution
10. Propose personal and professional development models to successfully onboard young engineers into the design-build process

1. Building Trust: Mentoring and Developing Successful Engineers
***Mark Gardner, P.E., Member**, McKinstry, Seattle, WA*

2. College to Contractor: Early Career Lessons from a Young Engineer
***Elise Kiland, P.E., Member**, Critchfield Mechanical, Inc, San Jose, CA*

3. Mind the Gap: Translating Design Build and Design Bid Build Lessons Learned across Project Delivery Methods
***Zachary Alderman, P.E., Member**, Opechee Construction Corporation, Belmont, NH*

9:45 AM - 10:45 AM

Seminar 23 (Intermediate)

Using District Energy Ground Source Heat Pumps to Reach your Decarbonization Goals

Track: HVAC&R Systems and Equipment
Room: Sheraton C (LC)
Sponsor: 6.2 District Energy, 6.8 Geothermal Heat Pump and Energy Recovery Applications
Chair: Tim Anderson, Applied Engineering Services, Inc, Indianapolis, IN
District energy or district heating and cooling is defined as means to distribute thermal energy to multiple buildings from a central plant. The traditional distribution method of heating has been steam primarily due to the compact size of piping. The use of GSHPs when applied to a district energy system allows for energy efficiency improvement, even providing means of totally electrifying the heating and cooling source. PV and/or wind power can be used directly within a campus grid. This seminar explores how that conversion can be accomplished and opens the pathway for decarbonization.

Learning Objectives:

1. Identify opportunities in model-based optimization for the control of community energy system with heterogenous energy sources

2. Explain how to reduce overall carbon emissions of the connected load
3. Describe the design principle of net zero energy community
4. Provide a method for financing the large capital cost needed to convert a steam system to a hydronic GSHP system
5. Identify opportunities in model-based optimization for the control of community energy system with heterogenous energy sources
6. Provide a method for financing the large capital cost needed to convert a steam system to a hydronic GSHP system

1. Ground Source Heat Pump Conversions and Financing
***Jeff Urlaub, P.E., Member**, MEP Associates, Eau Claire, WI*
2. Open-Source Modelica Library for Net Zero Energy Community with Water Source Heat Pumps
***Wangda Zuo, Ph.D., Member**, Pennsylvania State University, State College, PA*

9:45 AM - 10:45 AM

Forum 2 (Intermediate)

Moratorium on Evaporative Coolers: Giving a Whole New Meaning to the Energy-Water Nexus

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Dominion North (2)
Sponsor: 7.6 Building Energy Performance
Chair: Dennis Landsberg, Ph.D., P.E., Fellow Life Member, L&S Energy Services, Inc., Henderson, NV
The southwest is in a drought and the Southern Nevada Water Authority issued a moratorium on evaporative coolers for new building construction. The addition of mechanical cooling will change the partially conditioned space to a fully conditioned space. This will greatly increase the cost of construction, and likely the energy use and carbon footprint of warehouses, just when we are under tremendous pressure to reduce energy and carbon use. Spread of the moratorium to other states, new construction is likely and a moratorium on cooling towers is possible. This forum focuses on potential design solutions to this problem.

Monday, June 27, 11:00 AM - 12:00 PM

Conference Paper Session 10

Demand Control and Codes

Track: Connected Buildings, Connected Communities
Room: Osgoode (LC)
Chair: Mahroo Eftekhari, Ph.D., Member, Loughborough University, Loughborough, United Kingdom
The papers in this session relate to codes and standards, demand control and the interactive grid and building decarbonization.
Learning Objectives:

1. Recognize that healthcare occupancies, with their specific high-density energy and self-sufficiency requirements, must be identified as a unique building typology. The criticality of Hospitals to society will require a unique path to decarbonization.
2. Identify the potential risks to Hospitals on the path to decarbonization, particularly the risk to resiliency posed by the electrification of all systems and a growing reliance on intermittent electric generation resources.
3. Understand how renewable and energy efficiency measures interact in energy codes
4. Identify two ratios that can be used to compare efficiency and renewables in energy codes
5. Understand the history of Heating Degree Days (HDD) and its current applications
6. Describe the impact modern energy codes have on the HDD balance point
7. Describe the impact of ASHRAE Standards on government regulations. Understand the influence of ASHRAE Standards on design, testing, and rating guidelines in the HVAC&R industry.
8. Describe ASHRAE's support for academia and higher education. Learn about the professional development seminars, short courses, trainings, and certification programs ASHRAE offers to the industry.
9. Provide insights into choosing a suitable MPC formulation for a grid-interactive efficient building
10. Describe how different MPC settings affect building demand flexibility

1. Decarbonization of Hospitals, Maintaining Operational Resiliency with a Grid in Transition (TO-22-C032)
***Daniel Mastin, Associate Member**[1], Brian Kirk[1], Mike Rohan[2], Dan Chisholm[3], Rakesh Parasuraman[4], Rice Lummis[5] and Eric Bratcher[5], (1)New York Presbyterian Hospitals, New York, NY, (2)Northwell Health Systems, New York, NY, (3)MGI Consulting Inc., Winter Park, FL, (4)Luthin/5, Freehold, NJ, (5)Luthin/Energy by 5, Asbury Park, NJ*

2. Can Energy Codes Find the Right Balance between Two Good Choices: Efficiency and Renewables? (TO-22-C033)
Jim Edelson, Member[1], *Kim Cheslak, Member*[2], *Justin Baca*[3], *Joe Cain, P.E.*[3] *and Alexi Miller, P.E., Member*[1], *(1)New Buildings Institute, Portland, OR, (2)NBI, Portland, ME, (3)Solar Energy Industry Association, Washington, DC*

3. Heating Degree Days Relevancy: Why a 55-Degree Balance Point Is Better Than 65 for Building Energy Analysis in Heating Dominant Climates (TO-22-C034)
Kelly Thomas, Associate Member *and Mark Heizer, P.E., Member, State of Oregon - Building Codes Division, Salem, OR*

4. Impact and Value of ASHRAE's Standards and Technology (RP-1848) (TO-22-001)
Liping Liu, Ph.D., Associate Member[1], *Brent Bartone*[1], *Zahra Habib*[1], *Kinshuk Makhija*[1] *and Kashif Nawaz, Ph.D.*[2], *(1)Lawrence Tech University, Southfield, MI, (2)Oak Ridge National Laboratory, Oak Ridge, TN*

5. Demand Flexibility Evaluation for Building Energy Systems with Thermal Energy Storages Using Model Predictive Control (TO-22-C076)
Guowen Li, Student Member[1], *Yangyang Fu, Ph.D., Member*[1], *Amanda Pertzborn, Ph.D., Associate Member*[2], *Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE*[1] *and Jin Wen, Ph.D., Member*[3], *(1)Texas A&M University, College Station, TX, (2)NIST, Gaithersburg, MD, (3)Drexel University, Philadelphia, PA*

11:00 AM - 12:00 PM

Conference Paper Session 11

Variable Airflow Solutions and Modeling for Heating, Ventilation and Air Conditioning Systems

Track: HVAC&R Systems and Equipment

NY PDH G

Room: Sheraton C (LC)
Chair: Peng Yin, University of Louisiana at Lafayette, Lafayette, LA

Commercial buildings often use variable air volume systems to provide an efficient means of providing heating, cooling and ventilation to conditioned spaces. In this session, efforts to improve how VAV systems can be designed, built, simulated or used are discussed.

Learning Objectives:

1. know how to model variable airflow series FPTUs in EnergyPlus
2. Determine the energy savings due to replacing PSC motors with ECM motors in series FPTUs
3. Define LCC analysis in HVAC design in new configuration air-cooled VAV system.
4. Describe how to compare energy and cost saving in different climate zone based one LCC analysis.
5. Define various VAV system configurations and their differences
6. Describe how an efficient sequence of control can contribute to building energy consumption

1. Energy Modeling of Variable Airflow Series Fan Powered Terminal Units in EnergyPlus (TO-22-C035)
Zahra Sardoueinasab, Member[1], *Peng Yin*[2] *and Dennis O'Neal*[3], *(1)Nailor Industries, Houston, TX, (2)University of Louisiana at Lafayette, Lafayette, LA, (3)Baylor University, Waco, TX*

2. New Configurations and Control for Chilled Water VAV System with Air-Cooled Chillers (TO-22-C036)
Pejman Ebrahimi, AIA, Student Member*, Nabil Nassif and Iffat Ridwana, Student Member, University of Cincinnati, Cincinnati, OH*

3. Simulation and Field Experiments for Various Dual VAV System Controls and Configurations (TO-22-C037)
Iffat Ridwana, Student Member *and Nabil Nassif, University of Cincinnati, Cincinnati, OH*

11:00 AM - 12:00 PM

Seminar 24 (Intermediate)

Facilitating Integrated Project Delivery for Energy Efficiency: A Canadian Case Study

Track: Cold Climate Building System Design, Operation and Resilience
Room: Dominion South (2)
Sponsor: 7.1 Integrated Building Design
Chair: Elyse Malherek, Willdan, Minnetonka, MN

Integrated design and delivery require a collaborative effort from all parties throughout project lifecycle. This requires a shift in how we as an industry think about and deliver projects. This seminar discusses various aspects of integrated project delivery and strategies to implement an integrated design process for a unique Canadian project with high energy efficiency goals. The process

of evaluating HVAC and other energy efficiency measures to meet project sustainability goals will be discussed. Expect to take away ideas to incorporate integrated design for your future projects.

Learning Objectives:

1. Increase buy-in to the approach of Integrated Project Delivery
2. Explain the difference in the roles between the engineer, architect, and client
3. Describe technical facilitation skills to deliver integrated design successfully
4. Describe how energy simulation can be utilized throughout the process

1. Integrated Design from Conception through Occupancy
***Daniel Coursol**, Association Unie Local 144, Pointe-aux-Trembles, QC, Canada*

2. Facilitating IPD: An Architect's Perspective
***Sophie Marquet**, Blouin Tardif Architecture Environnement, Montreal, QC, Canada*

3. Sustainability and Energy Efficiency through Integrated Design in a Cold Climate
***Lianne Cockerton, P.Eng.**, Martin Roy et Associés, Montreal, QC, Canada*

11:00 AM - 12:00 PM

Seminar 25 (Basic)

LIVESTREAM: Fundamentals of Division 25: Integrated Controls and Cyber Security

Track: Connected Buildings, Connected Communities
Room: Grand East (LC)
Sponsor: 2.10 Resilience and Security, 7.5 Smart Building Systems
Chair: Beth Tomlinson, P.E., Member, Stantec, Minneapolis, MN
The built environment is quickly evolving into smart infrastructure, 5G Internet of Things and smart grid interoperability. Building interconnections provide an opportunity and target for cyber threats. This session presents the fundamentals of specification division 25, Integrated Controls, its benefits to smart building construction documents and the integration of cyber security in Operation Technology (OT) systems. In addition, we'll hear from real world HVAC&R hacks and resulting industry best practices.

Learning Objectives:

1. Describe the intent of division 25 specifications.
2. Explain the benefits of division 25 specifications to a high performance building.
3. Describe Cybersecurity concepts.
4. Apply Cybersecurity best practices.
5. Describe Cybersecurity concepts
6. Apply Cybersecurity best practices in a div 25 context

1. Benefits and Difficulties of Developing Division 25 Specifications
***Marcus Myers, AIA, BCxP, Associate Member**, Stantec, Phoenix, AZ*

2. Cybersecurity in a DIV25 Framework
***Wade Reda, Member**, Siemens, Toronto, ON, Canada*

11:00 AM - 12:00 PM

Forum 3 (Basic)

Decarbonization in Laboratory Buildings

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Dominion North (2)
Sponsor: 9.10 Laboratory Systems
Chair: Rachel Romero, P.E., Member, National Renewable Energy Laboratory, Golden, CO
Decarbonization of the buildings sector is a hot topic. Lab buildings are some of the highest energy consumers in the industry with complex ventilation requirements. Put the two together along with an overwhelming amount of policy and regulation, and the challenge to decarbonize the lab sector seems to be an impossible mission. This forum seeks to engage attendees on carbon reduction strategies, priorities, and capabilities. This is an interactive brainstorming session and active participation of the audience is required.

Presenter 1
***Rachel Romero, P.E., Member**, National Renewable Energy Laboratory, Golden, CO*

Monday, June 27, 2:15 PM - 2:45 PM

Sponsor Tech Talks (Basic)

ABB Motion solutions for Clean Room Environments

Room: Osgoode (LC)
Chair:
Ensuring reliable and energy efficient clean room environment - ABB experts will guide you through air treatment requirements for semiconductor manufacturing, pharmaceuticals, operating theaters, and laboratories and explain how ABB advanced motor and drive technologies can help with that.
Presenter 1
***Maria Fedorovicheva, M.D.**, ABB, Helsinki, Finland*
Presenter 2
***Riaan Van Jaarsveld**, ABB, Helsinki, Finland*

2:15 PM - 2:45 PM

Sponsor Tech Talks

Selling an HVAC/R Company: How to Prepare and What to Expect presented by Balmoral Advisors

Room: Dominion North (2)
Chair: Brooks Crankshaw, Balmoral Advisors, Chicago, IL
Well-managed HVAC/R companies continue to be in demand by potential buyers throughout North America. Market conditions are good for owners interested in selling their company at the highest value, either today or in the future. This talk will discuss what buyers are looking for, how to prepare the business for sale, and what to expect during the sale process.

This tech talk will be presented by Brooks Crankshaw, a Managing Director at Balmoral Advisors. He focuses on working with owners to sell their service companies, with an emphasis on the HVAC/R industry. Brooks earned a BA from the University of Michigan and an MBA from The Wharton School of the University of Pennsylvania.
Sponsor Tech Talk presented by Balmoral Advisors
***Brooks Crankshaw**, Balmoral Advisors, Chicago, IL*

2:15 PM - 3:45 PM

Debate 2 (Intermediate)

LIVESTREAM: Building Performance Standards: Are They Good for ASHRAE Members?

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: Task Force for Building Decarbonization
Chair: Paul Mathew, Lawrence Berkeley National Laboratory, Berkeley, CA, Travis English, P.E., Member, Kaiser Permanente, Anaheim, CA, Glenn Friedman, P.E., Fellow ASHRAE, Taylor Engineers, Alameda, CA, Kim Cheslak, Member, NBI, Portland, ME and Gina Bocra, New York City Department of Buildings, New York City, NY
Several jurisdictions (New York City, Washington DC, Washington State, and others) have recently adopted "building performance standards (BPS)" that establish energy or carbon performance requirements for existing buildings, in some cases with significant penalties if the requirements are not met. Are BPS good for ASHRAE members? Is there a way to inject more technical validity into development of BPS, which often are established through a political process? This debate discusses technical issues around the BPS that have been set, debates the pros and cons of some that are in place, and why ASHRAE members should care about them.

Tuesday, June 28

Tuesday, June 28, 8:00 AM - 9:30 AM

Conference Paper Session 12

Decarbonization and Net Zero Solutions using HVAC

Track: HVAC&R Systems and Equipment

Room: Osgoode (LC)

Chair: Rachel Romero, P.E., Member, National Renewable Energy Laboratory, Golden, CO

There is a substantial push toward improving the sustainability and decarbonization of buildings, including both new and existing buildings. As climate concerns and needed actions continue to mount, this session helps to discuss substantial efforts to support decarbonization and net-zero in buildings.

Learning Objectives:

1. Understand what a water wall is and how it can be used to precondition fresh air.
2. Apply techniques for integrating natural ventilation with multiple solar chimneys and decentralized ERV's
3. Apply strategies for achieving a net zero carbon mass timber academic buildings
4. Understand techniques for creating a natural ventilated building using solar chimneys
5. Design high performance future proof buildings with stringent emissions targets and apply these concepts for energy efficiency in various city buildings.
6. Describe how certain mechanical elements can be utilized to minimize operational energy consumption.
7. After attending this session, the attendees will be able to learn about new shock wave pressure exchanger technology that can provide significant energy savings for trans-critical CO2 refrigeration systems, especially in warmer climates.
8. After attending this session, the attendees will be able to learn about key mechanisms creating exergy destruction in refrigeration systems and how to recover lost pressure energy and use it to reduce the energy consumption of the main compressor.

1. A Hub for Collaboration: Toronto and Region Conservation Authority's New Headquarters (TO-22-C038)
Mike Godawa[1] *and Jamie Dabner*[2]*, (1)Integral Group, Toronto, ON, Canada, (2)Integral Group, TORONTO, ON, Canada*

2. Strategies to Achieve a Net ZeroCarbon, Mass Timber Academic Building (TO-22-C039)
Mike Godawa *and Pablo Casuso, Integral Group, Toronto, ON, Canada*

3. Future Proofing Toronto's Emergency Paramedic Facility – A Net-Zero Emissions Case Study (TO-22-C040)
Mudit Srivastava, Associate Member[1]*, Bhavin Degadwala*[2] *and Apoorv Goyal*[3]*, (1)Integral Group, Toronto, ON, Canada, (2)Integral group, Toronto, ON, Canada, (3)Elementa Engineering, New York City, NY*

4. New Types of Low Global Warming, Energy Efficient Refrigeration Architectures Using Trans-Critical Rotary Pressure Exchanger (TO-22-C041)
Azam Thatte, Ph.D.[1] *and Brian Fricke, Ph.D., Member*[2]*, (1)Energy Recovery, San Leandro, CA, (2)Oak Ridge National Laboratory, Oak Ridge, TN*

8:00 AM - 9:30 AM

Seminar 27 (Intermediate)

Bayesian Optimization for Building and Equipment Applications

Track: Fundamentals and Applications

Room: Dominion North (2)

Sponsor: 1.13 Optimization

Chair: Christopher Laughman, Ph.D., Member, Mitsubishi Electric Research Laboratories, Cambridge, MA

Bayesian optimization is an approach for optimizing complex systems which has attracted recent interest because of its ability to efficiently solve computationally expensive problems. This seminar introduces the fundamentals of Bayesian optimization to illustrate the benefits of this approach, and describe its application to a wide range of problems, including chiller plant design and control, simultaneous model calibration of both buildings and equipment, and the tuning of equipment control parameters to get optimal installed system performance.

Learning Objectives:

1. Define Bayesian optimization and explain the distinction between Bayesian optimization and other optimization methods
2. Apply the use of Bayesian optimization for approximating complex cost functions
3. Provide examples demonstrating the use of Bayesian optimization in both buildings and equipment applications
4. Describe how Bayesian optimization can be used to improve closed-loop control methods for next-generation building systems
5. Describe how Bayesian optimization can be used to improve closed-loop control methods for next-generation building systems
6. Learn examples demonstrating the use of Bayesian optimization in both buildings and equipment applications

1. Bayesian Optimization: An Efficient Approach for Designing and Assessing Building Systems
Veronica Adetola, Ph.D., Member*, Pacific Northwest National Laboratory, Richland, WA*

2. Meta-Learned Few-Shot Bayesian Optimization for Calibrating Physics: Informed Models of Coupled Building and HVAC Dynamics
Ankush Chakrabarty, Ph.D.*., Mitsubishi Electric Research Laboratories, Cambridge, MA*

3. MPC Tuning with Bayesian Optimization: A Case Study for HVAC Central Plants
Qiugang Lu, Ph.D.*., Texas Tech University, Lubbock, TX*

8:00 AM - 9:30 AM

Seminar 28 (Intermediate)

COVID-19 IAQ: Building Readiness and Resiliency in the New Age

Track: Buildings in the Aftermath of COVID-19
Room: Dominion South (2)
Sponsor: 1.12 Moisture Management in Buildings, Environmental Health Committee
Chair: Donald Snell, P.E., Associate Member, Liberty Building Forensics Group, Zellwood, FL
We will review what we have learned, what guidelines are in place and concerns moving forward relating to COVID -19 building readiness; COVID-19 mitigation strategies; epidemiology; and occupant trust. This includes analysis of key items from the ASHRAE Building Readiness Guide; a case study discussion of more than 100 buildings risk assessed prior to and after COVID-19 mitigation; a discussion on epidemiology: what we have learned and what studies are still needed and a case study discussion on the role and importance that occupant trust and perception have on the overall success of COVID-19 mitigation: lessons learned from 1990s IAQ.

Learning Objectives:

1. Describe the similarities to the public perception of IAQ from the 1990s to COVID-19 IAQ today
2. Explain the ETF Core Recommendations
3. Explain how different mitigation options compare to one another
4. Explain how COVID has been spreading in buildings
5. Understand the factors in assessing occupant risk.
6. Understand how occupants perceive that a building is safe
7. Recognize that occupant trust related to Covid-19 follows the same profile of IAQ and vacated sick buildings in the late 1980s and 1990s.
8. Explain the ETF Core Recommendations
9. Describe key items from the Building Readiness Guide

1. Will Occupants Trust That Your Building Is COVID-19 Safe?
Donald Snell, P.E., Associate Member*, Liberty Building Forensics Group, Zellwood, FL*

2. ASHRAE Epidemic Task Force Core Recommendations, Building Readiness and Key Concerns Moving Forward
Wade Conlan, P.E., BCxP, Member*, Hanson Professional Services, Maitland, FL*

3. Lessons Learned from COVID-19 Mitigation Measures in 100+ Buildings
Mike Carl*, RWDI, Canada*

4. What Does COVID Epidemiology Tell Us about the Effectiveness of HVAC Response Strategies?
Ed Light, Member*, Building Dynamics, LLC, Ashton, MD*

8:00 AM - 9:30 AM

Seminar 29 (Intermediate)

Deep Savings with ASHRAE Guideline 36: Demonstrations Today and Innovations for Tomorrow

Track: HVAC&R Systems and Equipment
Room: Provincial (2)
Sponsor: 1.4 Control Theory and Application
Chair: Hwakong Cheng, P.E., Member, Taylor Engineers, Tacoma, WA
ASHRAE Guideline 36 has rapidly grown in popularity since its first publication and offers the opportunity to significantly improve building energy efficiency and operational performance. This session presents work completed as part of a California Energy Commission study, titled EPIC Best in Class, which focused on demonstrating cost effective energy savings in existing buildings by improving building automation systems, such as with Guideline 36. Speakers present the results from several successful demonstration projects, provide an overview of the current and future marketplace, and highlight two concepts that were piloted to streamline the use of Guideline 36 in the future.

Learning Objectives:

1. Summarize the energy savings opportunities with Guideline 36
2. Describe various Guideline 36 implementation challenges and best practices
3. Provide an overview of efforts underway to support market adoption of Guideline 36
4. Describe an approach to validate Guideline 36 programming logic
5. Summarize the energy savings opportunities with Guideline 36
6. Describe various Guideline 36 implementation challenges and best practices
7. Provide an overview of efforts underway to support market adoption of Guideline 36.
8. Summarize how G36 improves BAS delivery process.
9. Summarize the energy savings opportunities with Guideline 36
10. Describe various Guideline 36 implementation challenges and best practices
11. Provide an overview of efforts underway to support market adoption of Guideline 36
12. Describe an approach to validate Guideline 36 programming logic
13. Understand why programming validation is required
14. Describe an approach to validate Guideline 36 programming logic

1. Proving the Potential: Field Demonstrations of ASHRAE Guideline 36 Retrofits
***Curtis Fong, P.E., Member**, Taylor Engineers, Alameda, CA*

2. Driving Market Adoption of ASHRAE Guideline 36
***Rupam Singla, P.E., Member**, TRC, Oakland, CA*

3. Model-Based Estimation of Energy Savings from ASHRAE Guideline 36
***David Blum, Ph.D., Member**, Lawrence Berkeley National Laboratory, Berkeley, CA*

4. ASHRAE Guideline 36 Certification: A Pilot Approach for Guideline 36 Programming Validation
***Reece Kiriu, P.E., Member**, Taylor Engineers, Alameda, CA*

8:00 AM - 9:30 AM

Seminar 30 (Intermediate)

The Solar Panel: Enabling Renewables' Grid Integration with Thermal Energy Storage Systems

Track: Connected Buildings, Connected Communities
Room: Grand East (LC)
Sponsor: 6.9 Thermal Storage
Chair: Jason Woods, Ph.D., Associate Member, National Renewable Energy Laboratory, Golden, CO
Integrating renewable electricity on the grid requires system flexibility. This flexibility can come from several building end-uses, but it should not impact occupant comfort or safety. This is possible by using thermal energy storage, which enables flexibility of HVAC&R loads while still delivering cooling, heating or domestic hot water when needed. This session presents three grid-connected thermal storage applications that reduce utility costs for building owners while also providing flexibility that the grid needs for higher renewable penetration. The presenters describe how smart controls are critical to facilitate renewable electricity generation, and, in one application, electric vehicle charging.

Learning Objectives:

1. Explain how water heaters can provide demand side management to the grid.
2. Identify effects of load shifting on end-user electricity bills and the use of solar-self consumption.
3. Describe how a phase-change-material-based cool thermal energy storage system can be used to enable renewables on the electric grid.
4. Describe the pros and cons of behind-the-meter battery and thermal energy storage, and how to select the appropriate combination depending on the building load profile.
5. Explain how water heaters can provide demand side management to the grid
6. Identify effects of load shifting on end-user electricity bills and the use of solar-self consumption
7. Describe how a phase-change-material-based cool thermal energy storage system can be used to enable renewables on the electric grid.
8. Identify effects of load shifting on end-user electricity bills and the use of solar-self consumption.
9. Describe the pros and cons of behind-the-meter battery and thermal energy storage
10. Understand how to select the appropriate combination depending on the building load profile

1. Optimization of Photovoltaic Self-Consumption with Residential Electric Water Heaters
***Celeste Fieberg, Student Member**, Lafayette College, Easton, PA*

2. Enabling Grid Penetration of Renewables with Residential Cool Thermal Energy Storage
***Amy Van Asselt, Ph.D., Associate Member**, Lafayette College, Easton, PA*

3. Synergies between Building-Sited Batteries and Thermal Energy Storage
***Jason Woods, Ph.D., Associate Member**, National Renewable Energy Laboratory, Golden, CO*

8:00 AM - 9:30 AM

Seminar 31 (Intermediate)

Your Ethics Tool Box: Building a Framework for Ethical Decision-Making with Case Studies

Track: Professional Development and Education
Room: Sheraton C (LC)
Sponsor: 1.7 Business, Management & General Legal Education
Chair: Mike Bilderbeck, P.E., Fellow ASHRAE, Pickering, Inc., Memphis, TN
ASHRAE members are often confronted with ethical issues (whether they realize it or not). This session is part of a continuing program under which ASHRAE members engage in an interactive session where participants are presented with multiple ethics cases, discuss the cases in small groups, and then reveal their decisions. Test your "Ethics IQ" against real cases and receive CE credit in the process.

Learning Objectives:

1. Explain why decisions to ethical issues are often "situational"
2. Explain why decisions to ethical questions may depend on the perspective of the decider
3. Explain an engineer's "priorities of loyalty"
4. Describe why lapses in proper ethical behavior can have long-reaching consequences

1. Case Studies One and Two
***Jennifer Leach, P.E., Member**, United Energy Products, Baltimore, MD*

2. Case Studies Three and Four
***Michael Cooper, P.E., Member**, Bernhard, Metairie, LA*

3. Case Studies Five and Six
***Mike Bilderbeck, P.E., Fellow ASHRAE**, Pickering, Inc., Memphis, TN*

Tuesday, June 28, 9:45 AM - 10:45 AM

Poster 13

Fundamentals and Modelling: Part 1 (Posters)

Track: Fundamentals and Applications
Room: Osgoode (LC)
Chair: James VanGilder, P.E., Member, Schneider Electric, Andover, MA

Poster Sessions begin with each author giving a brief oral overview of their paper, then going to their poster stations to respond to any questions attendees may have regarding the work reported on. The papers in this session relate to the fundamentals of modelling climates, buildings, equipment heat transfer and district heating/cooling systems.

Learning Objectives:

1. distinguish the importance of urban microclimate and identify the key parameters for the model output variations in building energy modelling (BEM).
2. understand the potential of two alternative approaches, City Fast Fluid Dynamics (CityFFD) and the Urban Weather Generator (UWG), for predicting urban microclimate and its BEM impacts for the case study of the hot arid climate.
3. Describe how to estimate unknown parameters using Machine Learning model such as Generative Adversarial Networks (GAN)
4. Explain model calibration process with estimating parameters' probability distribution using GAN model
5. Understand the insights from a large machine learning competition focused on building energy prediction
6. Distinguish best practices of developing machine learning solutions for built environment applications.
7. Understand challenges and limitations of district cooling systems and their associated design considerations
8. Have a sense of large system design in excess of building considerations but also the environment the building sits in

1. Comparing Two Simulation Approaches for Quantifying Urban Microclimate Impact on Building Energy Performance (TO-22-C043)
Dongxue Zhan, Student Member[1], *Danlin Hou, Student Member*[1], *Liangzhu Wang*[1] *and Ibrahim Hassan, Ph.D., P.E., Member*[2], *(1)Concordia University, Montreal, QC, Canada, (2)Mechanical Engineering Department, Texas A&M at Qatar, Doha, Qatar*

2. Gan-Based Parameter Estimation of Building Energy Model (TO-22-C045)
Hansol Shin, Ph.D. *and Cheol-Soo Park, Ph.D., Seoul National University, Seoul, Korea, Republic of (South)*

3. Gradient Boosting Machines and Careful Pre-processing Work Best: ASHRAE Great Energy Predictor III Lessons Learned (TO-22-C046)
Clayton Miller, Ph.D., Member*, Hao Liu, Student Member and Chun Fu, Student Member, National University of Singapore, Singapore, Singapore*

4. Sea Water Cooled Chiller Plant and Other District Cooling Systems Viability, Selection Criteria and Master Planning (TO-22-C048)
Chris KW Leung, P.Eng., Member*, Cundall HK Ltd, Hong Kong, Hong Kong*

9:45 AM - 10:45 AM

Conference Paper Session 14

Solar-Powered Solutions for Supporting Building Operations

Track: HVAC&R Systems and Equipment

NY PDH G

Room: Sheraton C (LC)
Chair: Ahmed Elatar, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN

Solar energy is a freely available resource that can be harvested to support improved efficiency and performance of buildings, helping move towards net-zero building solutions. In this session, efforts to improve the use of solar energy, including for pre-heating of HVAC fresh air, and for building integrated photovoltaics will be explored.

Learning Objectives:

1. Design and Model an Outdoor HVAC Duct exposed to Solar Radiation
2. Perform Integrated Ventilation and Noise Assessment
3. Identify what a Double Skin Facade integrating Semi-Transparent PV is.
4. Identify the role of selecting different flow strategies for the cavity of the DSF

1. Design, Ventilation and Noise Assessment of an Outdoor HVAC Duct Exposed to Solar Radiation for Pre-Heating of Fresh Air (TO-22-C049)
Himanshu Dehra*, Monarchy of Concordia, Wellstar Beacon Labs, Faridabad, India*

2. Double Skin Façade Integrating Semi-Transparent Photovoltaics: A Case Study for Different Climates (TO-22-C050)
Zisis Ioanndis, Student Member*, Andreas Athienitis, Ph.D., P.E., Fellow ASHRAE, Ted Stathopoulos, Ph.D., P.E., Member and Stratos Rounis, Concordia University, Montreal, QC, Canada*

9:45 AM - 10:45 AM

Seminar 32 (Intermediate)

LIVESTREAM: Climate Change Issues for Decarbonization, IAQ and Sustainable Buildings

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: 2.5 Global Climate Change, 2.8 Building Environmental Impacts and Sustainability, TC 2.10 Resilience and Security; TC 7.4 Exergy Analysis for Sustainable Buildings; TC 4.2 Climatic Information
Chair: Elizabeth Tomlinson, P.E., Member, Stantec, Minneapolis, MN
Climate change is making a significant mark on many issues besides increased energy use. Air quality is one area where increased effort will be needed to assure health in buildings due to gradual chemical changes in the atmosphere alongside acute changes caused by climate driven extreme events. Of equal concern are competing and disparate efforts to decarbonize (mitigate climate change) and to increase resilience (increase adaptive capacity) of the built environment. These issues and their associated complexities are discussed in this seminar.

Learning Objectives:

1. Explain how climate change is worsening air quality and impacting health outcomes
2. Explain the need to think beyond air pollution when considering IAQ risk
3. Describe the key differences between the drivers that support climate-related mitigation and those that support climate-related adaptation.
4. Describe 2 possible solutions that help to address both decarbonization and climate-related resilience within the HVAC designers' influence
5. How climate change is worsening air quality and impacting health outcomes.
6. The need to think beyond air pollution when considering IAQ risk.

1. The Shocks and Stressor of Climate Change and the Impact upon IAQ and Occupant Health
***Joss Hurford, P.E.**, AEI Engineering, Maddison, WI*

2. The Fraternal Twins of Decarbonization and Climate Resilience
***Erin McConahey, P.E., HBDP, Fellow ASHRAE**, Arup, Los Angeles, CA*

9:45 AM - 10:45 AM

Seminar 33 (Intermediate)

The Future of Controls: Transition from Algorithmic to Predictive Control

Track: HVAC&R Systems and Equipment
Room: Dominion North (2)
Sponsor: 1.4 Control Theory and Application
Chair: Paul Ehrlich, P.E., Building Intelligence Group, Afton, MN
Grid interactive energy efficient buildings will require control systems that are able to balance out the needs to provide for a safe, comfortable and efficient building environment while at the same time coordinating the operation of the building with the needs of the grid. The use of new technology including model predictive control can provide solutions that are able to both control and estimate future needs using data and simplified building models. This session looks at the pros and cons of these new approaches and discuss potential research needs and direction for industry.

Learning Objectives:

1. Describe MPC and how it is an effective solution for both control as well as predicting building behavior
2. Identify key issues to be further considered by the research community and industry
3. Explain how to use predictive control on current and future projects
4. Describe the research efforts underway to support new control technologies
5. To understand what proxy sensing is and how it can be useful.
6. To be able to differentiate between model-based predictive control and rule extraction control.

1. Why and How You Should Make Model-Based Predictive Control Work for You?
***Draguna Vrabie, Ph.D., Member**, Pacific Northwest National Laboratory, Richland, WA*

2. Digital-Twin Based Control Technology Enables Fully Autonomous Building Systems: Meeting and Exceeding Level 5 Autonomy
***Troy Harvey, Member**, PassiveLogic, Salt Lake City, UT*

3. In-Situ Field Testing of Model-Based Predictive Control (MPC) and Simplified MPC in an Institutional Building
***Jayson Bursill, Ph.D., Member**, Delta Controls Inc., Surrey, BC, Canada*

9:45 AM - 10:45 AM

Seminar 34 (Advanced)

Thermal and Hydraulic Performance of Low GWP Refrigerants under Flow Condensation

Track: HVAC&R Systems and Equipment
Room: Dominion South (2)
Sponsor: 1.3 Heat Transfer and Fluid Flow, MTG.LowGWP Lower Global Warming Potential Alternative Refrigerants , TC 8.4, TC 8.5
Chair: Kashif Nawaz, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN
The environmental impact of conventional HFC refrigerants and their subsequent phasing out has led to the evaluation of heat transfer and pressure drop performance of alternative low-GWP refrigerants. This seminar highlights the flow condensation performance of several low-GWP refrigerants, both pure and HFC/HFO mixtures, in 0.95 mm multi-channels tube, and smooth and internally enhanced microfin tubes of 4 mm to 9 mm diameter. R-32, R-1234yf, R-454C, R-450A, and R-513A were experimentally investigated to compare with R134a and R410A, and with existing correlations. This session benefits engineers with refrigerant selection and design of air-to-refrigerant and liquid-to-refrigerant heat transfer equipment.

Learning Objectives:

1. Understand how condensation heat transfer coefficients and pressure drops are measured.
2. Learn how low GWP refrigerants' flow condensation performances compares to R134a and R410A.
3. Learn how correlations predict performance of new low GWP refrigerants.
4. Review enhancement mechanisms of microfin tubes and how they can impact non-azeotropic condensation in horizontal tubes.
5. Understand how condensation heat transfer coefficients and pressure drops are measured.
6. Learn how low GWP refrigerants' flow condensation performances compares to R134a and R410A.
7. Choose the best heat transfer and pressure drop correlation for condensation of R454B and R32 in a smooth tube.
8. See the initial comparison of the heat transfer and pressure drop data for R454B and R-32 in an enhanced (straight fin) and expanded Aluminum tube.
9. The effective condensation performance of R32 in smooth and microfin mini tubes.
10. The comparison between R32 and R410A during condensation inside either smooth or microfin mini tubes.
11. The most effective operating conditions to design efficient condensers with mini microfin tubes operating with R32
12. explain the potential enhancement mechanism of microfin tubes for zeotropic mixtures.
13. describe the change in heat transfer behavior of zeotropic mixture in microfin tubes with diameter and flow regime.

1. Condensation Heat Transfer Performance of R513A and R450A in Minichannel Square Tubes
***Melanie Derby, Ph.D., Member**, Kansas State University, Manhattan, KS*

2. Condensation Heat Transfer and Pressure Drop for Single Component and Refrigerant Mixtures in Smooth and Enhanced Tube Geometries
***Saad Jajja, Ph.D.**, Oak Ridge National Laboratory, Oak Ridge, TN*

3. Condensation of R32 inside Microfin and Smooth ID 4mm Tubes: A Direct Experimental Comparison
***Simone Mancin, Ph.D.**, University of Padova, Padua, TN, Italy*

4. Condensation of Low Global Warming Potential Non-Azeotropic Mixture R454C in Horizontal Microfin Tubes
***Brian M. Fronk, Ph.D., P.E., Associate Member**, Oregon State University, Corvallis, OR*

9:45 AM - 10:45 AM

Seminar 35 (Intermediate)

Indoor Environment, Thermal Comfort and Work Performance: Evidence, Models and Implications

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Provincial (2)
Sponsor: 2.1 Physiology and Human Environment
Chair: Pawel Wargocki, Ph.D., Associate Member, Technical University of Denmark, Kongens Lyngby, Denmark
The indoor environment plays an important role in our perception, comfort and work performance either physically or cognitively. This seminar aims to disseminate some latest research on this topic by aggregating studies with new evidence and models. The presentations advance our understanding of thermal comfort prediction, the influence of thermal environment on

physical and cognitive work performance, and the effects of mask-wearing on thermal comfort and cognition. The results can shed light on future indoor environment design and operation.

Learning Objectives:

1. Describe the impact of climate on physical work capacity in terms of temperature, humidity, air speed and thermal radiation
2. Explain the effect of mask-wearing on thermal comfort and cognition
3. Describe the accuracy of the PMV/PPD model at the base of ASHRAE 55
4. Define the impact of temperature on work performance

1. Influence of Climate on Physical Work Performance
***Josh Foster**, Texas Health Resources, Dallas, TX*

2. Are There Temperature Limits Regarding Work Performance?
***Pawel Wargocki, Ph.D., Associate Member**, Technical University of Denmark, Kongens Lyngby, Denmark*

Tuesday, June 28, 11:00 AM - 12:30 PM

Panel 1 (Basic)

Young Engineers in ASHRAE Mentorship Panel Discussion with College of Fellows

Track: Professional Development and Education
Room: Provincial (2)
Sponsor: Young Engineers in ASHRAE, College of Fellows
Chair: Shona O Dea, Associate Member, DLR Group, Chicago, IL

ASHRAE members at any stage of their career will benefit from this interactive panel discussion between a diverse group of YEA and the College of Fellows members. Mentorship does not just happen; it's important to be intentional about finding and nurturing relationships, both with those that fill experience gaps, but also with peers to achieve your highest potential. It's the goal of this panel for new and seasoned members of ASHRAE to develop their skills, knowledge and confidence around navigating through the organization and avail of all it has to offer such as technical, standing and grassroots committees.

Learning Objectives:

1. Understand what Mentorship is and how such a program works.
2. Learn from a Mentors point of view the challenges and and advantages of participating in a mentorship experience.

1. YEA Mentorship Panel Discussion with College of Fellows 1
***Katherine Hammack**, U.S. Green Building Council, Washington DC, DC*

2. YEA Mentorship Panel Discussion with College of Fellows 2
***Mark W. Fly, P.E., Fellow ASHRAE**, AAON Inc., Tulsa, OK*

3. YEA Mentorship Panel Discussion with College of Fellows 3
***Tom Lawrence**, DLR Group, Chicago, IL*

4. YEA Mentorship Panel Discussion with College of Fellows 4
***Dennis Knight, P.E., Fellow ASHRAE**, Whole Building Systems, LLC, Mt. Pleasant, SC*

11:00 AM - 12:30 PM

Poster 15

Fundamentals and Modelling: Part 2 (Posters)

Track: Fundamentals and Applications
Room: Osgoode (LC)
Chair: Nohad Boudani, PEng, Member, Sodicom, Beirut, Lebanon

Poster Sessions begin with each author giving a brief oral overview of their paper, then going to their poster stations to respond to any questions attendees may have regarding the work reported on. The papers in this session relate to modelling cooling towers, pipe pressure losses, the impact of commissioning on peak electric demand, creating building archetypes and using historical data to determine building loads.

Learning Objectives:

1. How cooling towers could be installed at different levels or even beneath a chiller plant and operate

2. Why it is a bad idea to install cooling towers at different levels
3. Discuss how to use historical data to review cooling loads
4. Identify the range of historical cooling loads and diversities in common health care spaces.
5. After attending this session, the attendees will be able to make an educated decision on the methodology to use for developing building archetypes for specific regions
6. After attending this session, the attendees will be able to define the most important parameters for calibration to develop a building archetype for a specific region
7. measure the pressure losses due to pipe fittings
8. design or select devices and instrument for pressure loss measurement
9. understand how different existing building commissioning (EBCx) measures affect the electric peak demand of the facility
10. Understand the modeling simulation procedure that was used in this study, and how to replicate at other facilities and climate zones to conduct a similar study.

1. Design and Operation of Cooling Tower at Different Height Levels (TO-22-C052)
***Chris KW Leung, P.Eng., Member**, Cundall HK Ltd, Hong Kong, Hong Kong*

2. Determining Internal Loads in Health Care Clinical Spaces Using Historical Data (TO-22-C053)
***Stet Sanborn, AIA, Member**[1], Travis English, P.E., Member[2], Maya Salabasheva, P.E., Member[3], Jun Timbang[3], Peter McNally[1], Victor Braciszewski[1], Eli Cowart[1], Armen Topakian[1], Ben Apolinario[3] and Herb Moussa[1], (1)Smith Group, San Francisco, CA, (2)Kaiser Permanente, Anaheim, CA, (3)Kaiser Permanente, Oakland, CA*

3. Evaluating Approaches to Developing Building Energy Archetype Models Under Uncertainties (TO-22-C054)
***Majd Moujahed**[1], Liangzhu Wang[1], Danlin Hou, Student Member[1] and Ibrahim Hassan, Ph.D., P.E., Member[2], (1)Concordia University, Montreal, QC, Canada, (2)Mechanical Engineering Department, Texas A&M at Qatar, Doha, Qatar*

4. Measurement Methods and Techniques of Pressure Losses of Pipe Fittings (TO-22-C055)
***Lingnan Lin, Ph.D.**[1], Marylia Duarte Batista[1] and Natascha Milesi Ferretti, P.E., Member[2], (1)National Institute of Standards and Technology, Gaithersburg, MD, (2)National Institute of Science and Technology, Gaithersburg, MD*

5. Optimal Zone Minimum Airflow Set Point for Multi-Zone VAV Air-Handling Unit (TO-22-C056)
***Nabil Nassif, Ph.D., P.E., Member**, University of Cincinnati, Cincinnati, OH*

6. The Impact of Existing Building Commissioning Measures on Electric Peak Demand (TO-22-C057)
***Ahmed Morsy, Student Member**[1], David Claridge, Ph.D., P.E., Fellow ASHRAE[1] and Walter Williams, P.E.[2], (1)Texas A&M University, College Station, TX, (2)Tarrant County College District, Fort Worth, TX*

11:00 AM - 12:30 PM

Conference Paper Session 16

Occupants and Comfort in Buildings

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings

NY PDH G

Room: Sheraton C (LC)
Chair: Luke Leung, P.E., Member, Skidmore, Owings, & Merrill LPP, Chicago, IL
Buildings are design for the occupants for which they provide a comfortable indoor climate. Occupants, however, are often challenging to predict in terms of behavior. In addition, comfort conditions can change depending on the people and their preferences. In this session, methods to model occupants and their behavior are presented, along with efforts to improve occupant comfort and reduce discomfort.

Learning Objectives:

1. Discuss several different methods of thermal comfort analysis, and know what kind of inputs are required to calculate them.
2. Evaluate long-term thermal comfort by continuously monitoring zone air temperature sensor data.
3. Discuss several different methods of thermal comfort analysis, and know what kind of inputs are required to calculate them.
4. Compare different methods of thermal comfort analysis in the context of a BC building.
5. Evaluate long-term thermal comfort by continuously monitoring zone air temperature sensor data.
6. Develop or execute long-term thermal comfort evaluation application on Mortar testbed.
7. Understand the nationwide cost savings of the occupancy sensing systems.
8. Quantify the economic benefits of the occupancy sensing systems using NS, SIR, and DPB.

1. A Practical Method to Account for Different Possible Occupant Behaviors during Design Phase (TO-22-C059)
***Debby Veillette, Student Member**, Jean Rouleau, Ph.D., P.E., Member and Louis Gosselin, Ph.D., P.E., Member, Université Laval, Quebec City, QC, Canada*

2. Analysis of Acceptability Limits for Determining Overheating Risk of Passively Cooled Buildings in British Columbia (TO-22-C060)
***Maddy Kennedy-Parrott, Member**, Read Jones Christoffersen, Vancouver, BC, Canada*

3. Enabling Portable and Reproducible Long-Term Thermal Comfort Analytics with Brick Schema and Mortar Data (TO-22-C061)
***Ruiji Sun, Student Member**[1], Carlos Duarte Roa, Ph.D., Member[1], Paul Raftery, Ph.D., Member[1] and Gabe Fierro, Ph.D.[2], (1)University of California, Berkeley, CA, (2)Colorado School of Mines, Golden, CO*

4. Monetary Savings of Occupancy-Centric Control in Commercial Buildings (TO-22-C062)
***Zhihong Pang, Student Member**[1], Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE[1], Jian Zhang, Ph.D., Member[2], Hwakong Cheng, P.E., Member[3], Yan Chen, Ph.D.[4] and Bing Dong, Ph.D., Associate Member[5], (1)Texas A&M University, College Station, TX, (2)Pacific Northwest National Laboratory, Richland, WA, (3)Taylor Engineering LLP, Tacoma, WA, (4)Pacific Northwest National Laboratory, Portland, OR, (5)Syracuse University, Syracuse, NY*

11:00 AM - 12:30 PM

Seminar 36 (Intermediate)

Balancing Comfort, Energy and IAQ in Buildings: Examples from Real World Applications

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Dominion North (2)
Sponsor: 4.10 Indoor Environmental Modeling
Chair: Wangda Zuo, Ph.D., Member, Pennsylvania State University, State College, PA
This seminar introduces how to use advanced modeling technique to balance the comfort, IAQ and energy in buildings. Speakers demonstrate that by using different real-world applications for different climates. Both mechanical ventilation and natural ventilation is discussed.

Learning Objectives:

1. Provide a guideline for how CFD can be efficiently provide inputs to the ventilation system from concept to design to improve thermal comfort and IAQ while reducing energy consumption
2. Outline the CFD modeling requirements for DV from mesh to solver
3. Explain how a DV system can be designed an integrated into an architecturally complex space in a harsh climate
4. Describe the method of the co-simulation of CFD and EnergyPlus models
5. Describe the method of the co-simulation of CFD and EnergyPlus models
6. Explain key inputs for both CFD and EnergyPlus simulations considering local standards/codes, and weather conditions in arid climates

1. Impacts of Urban Microclimate on Building Cooling Loads in Arid Climates
***Liangzhu Wang**, Concordia University, Montréal, QC, Canada*

2. Design Nuances of a Middle Eastern Airport Terminal
***Mike Koupriyanov, P.E., Associate Member**, Price Industries Limited, Winnipeg, MB, Canada*

3. Regional Weather Extremes and Displacement Ventilation: A Look at a Boston Logan's International Terminal
***Duncan Phyfe, Associate Member**, Alden Research Laboratory, Holden, MA*

4. Challenges of Keeping Elevator Cores Dry in Naturally Ventilated Elevator Cores in Hot Humid Climates
***Duncan Phillips, Ph.D., P.E., Member**, Rowan Williams Davies & Irwin, Guelph, ON, Canada*

11:00 AM - 12:30 PM

Seminar 37 (Basic)

LIVESTREAM: COVID-19 and Indoor Air Filtration

Track: Buildings in the Aftermath of COVID-19
Room: Grand East (LC)
Sponsor: 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment
Chair: Kyung-Ju Choi, Ph.D., Member, Clean & Science, Louisville, KY

COVID-19 has crucially influenced decisions about proper indoor air filtration levels to secure occupant health. This seminar has two objectives. First, it provides information on filter effectiveness to prevent transmission of airborne COVID-19 particles. Second, it describes new performance standards for portable air cleaners.

Learning Objectives:

1. Describe the methods of airborne infectious disease transmission
2. Identify the basic principles of current technologies for the removal of COVID-19 particles
3. Define current performance standards for testing the air cleaners, and the effectiveness of air filter devices
4. Provide information that would help to stop the spread of COVID-19 particles
5. After attending the session, attendees should be able to describe the methods of airborne infectious disease transmission
6. After attending the session, attendees should be able to identify the basic principles of current technologies for the removal of COVID-19 particles
7. After attending the session, attendees should be able to define current performance standards for testing the air cleaners, and the effectiveness of air filter devices
8. After attending the session, attendees should be able to provide information that would help to stop the spread of COVID-19 particles
9. Design Apply
10. Understand how portable air cleaners are tested for microbiological reduction

1. Effectiveness of HVAC Filters and Room Air Purifiers at Mitigating Indoor Particulate Matters
***John Zhang, Ph.D., Member**, 3M, St. Paul, MN*

2. Modeling the Transmission Risk and Control of COVID-19 in Indoor Environments
***Parham Azimi, Ph.D., HFDP**, Harvard T.H. Chan School of Public Health, Boston, MA*

3. Standard Development Activities in North America Associated with Portable Air Cleaner Device Capabilities to Mitigate Potential Health Risks
***Randall Cooper, Member**, Association of Home Appliance Manufacturers, Washington, DC*

11:00 AM - 12:30 PM

Seminar 38 (Basic)

Fundamentals of Climate Science, Part 1: History and Physics

Track: Fundamentals and Applications
Room: Dominion South (2)
Sponsor: 2.5 Global Climate Change, 4.2 Climatic Information, 2.8 Building Environmental Impacts and Sustainability
Chair: Daniel Villa, P.E., Member, Sandia National Laboratories, Alamo (virtual employee), TX
The Intergovernmental Panel on Climate Change 2021 reports show that anthropogenic effects on climate change are unequivocal. Human influence is a primary cause of the warming affect to our climate currently being observed. As a result, understanding climate science fundamentals is becoming increasingly important. Regardless, much of the engineering community has not been able to focus their attention on climate science. This seminar provides basic history, physics and modern developments in climate science. Materials are presented from several sources including a free course from Penn State University and ASHRAE's Fundamentals chapter 36 on climate change.

Learning Objectives:

1. Explain how climate science has developed for 200 years
2. Elaborate on the basic principals of black body radiation and the green house gas effect
3. List the major earth climate system feedbacks
4. Identify multiple strands of evidence that have made global warming an unequivocal scientific result
5. Elaborate the basic principals of black body radiation and the green house gas effect
6. List the major earth climate system feedbacks
7. understand the major earth climate system feedbacks, understand the development of Earth Climate Modeling System
8. learn more about multiple strands of evidence that have made global warming an unequivocal scientific result

1. Climate Science History
***Scott Sherwood**, Eco Care Corporation, New York, NY*

2. Physics of Earth's Climate: Understanding Global Warming
***Daniel Villa, P.E., Member**, Sandia National Laboratories, Alamo (virtual employee), TX*

3. Recent Developments and Measurements
***Xin Qiu, Ph.D., Member**, SLR / Novus Environmental Inc., Guelph, ON, Canada*

Tuesday, June 28, 1:30 PM - 3:00 PM

Seminar 39 (Intermediate)

LIVESTREAM: A Tool to Decarbonize Existing Buildings: An Overview of ASHRAE's Technical Resource Guide on Building Performance Standards

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: SSPC 100, Task Force for Building Decarbonization
Chair: Bing Liu, P.E., Fellow ASHRAE, Pacific Northwest National Laboratory, Portland, OR
Building Performance Standards (BPS) are powerful policy instruments adopted by states and cities to improve the energy performance and reduce GHG emissions of existing buildings. In the U.S, BPS policies are being considered for implementation at both the federal level and by over 30 jurisdictions as part of a National BPS Coalition. This session introduces ASHRAE's BPS Technical Resource Guide, which will provide jurisdictions with the necessary technical knowledge for the development of a BPS. Participants will learn about different performance metrics and targets, implementation challenges technically and financially, and opportunities to ASHRAE members to support building owners in compliance.

Learning Objectives:

1. Describe the key elements needed for a comprehensive Building Performance Standard
2. Explain the impacts of selecting different BPS metrics and provide an overview of different BPS target-setting methodologies
3. Explain how the BPS Technical Resource Guide for Policymakers can support jurisdictions in the development of BPS policies
4. Describe the impact of BPS on the practicing engineer and design team including the necessary technical knowledge for implementing BPS as described by the ASHRAE BPS Technical Guide.
5. Understand ASHRAE's Technical Guide on Building Performance Standard and how to use it for BPS design and compliance.
6. Describe the key elements needed for a comprehensive Building Performance Standard
7. Explain how the BPS Technical Resource Guide for Policymakers can support jurisdictions in the development of BPS policies
8. Describe the key elements needed for a comprehensive Building Performance Standard
9. Provide an overview of the process for setting Building Performance Standards targets
10. Explain the differences and advantages of different types of BPS metrics
11. Describe major considerations for establishing the scope of a BPS
12. Understand the consulting engineers building performance standard work process.
13. Understand the consulting engineers building performance standard work team coordination requirements.

1. Overview of ASHRAE's Technical Guide on Building Performance Standards
***Bing Liu, P.E., Fellow ASHRAE**, Pacific Northwest National Laboratory, Portland, OR*

2. City and State Ambitions on Energy Efficiency: A Policy Primer
***Dave Ribeiro**, The American Council for an Energy-Efficient Economy, Washington DC, DC*

3. Developing Performance Standards: Target-Setting and Considerations
***Andrea Mengual, P.E.**, Pacific Northwest National Laboratory, Seattle, WA*

4. How Do We Get There from Here? Examining the Paths to Achieve Decarbonization Policy Goals
***Amy Boyce, P.E., Member**, Institute of Market Transformation, Washington DC, DC*

5. A Consulting Engineer's Preview of ASHRAE's Technical Guide for Building Performance Standards
***Glenn Friedman, P.E., Fellow ASHRAE**, Taylor Engineers, Alameda, CA*

Tuesday, June 28, 3:15 PM - 4:45 PM

Panel 2 (Basic)

LIVESTREAM: ASHRAE and DEI: Where Are We Now, Where Do We Want to Be Tomorrow and How Do We Get There?

Track: Professional Development and Education
Room: Grand East (LC)
Sponsor: BOD DEI Advisory Subcommittee
Chair: Sheila Hayter, Member, Energy & Environmental Applications, National Renewable Energy Laboratory, Golden, CO
In 2021, ASHRAE's Board of Directors approved the formation of the BOD Diversity, Equity and Inclusion (DEI) Advisory Subcommittee, with goals on improving organizational awareness and performance on DEI, setting annual budgets for DEI programs and ongoing initiatives and prioritizing inclusivity in ASHRAE with plans for addressing these issues. What progress

has been made over the past year towards these goals? What needs to be done? During this interactive panel discussion hear from a diverse panel, including members of the advisory subcommittee, as we review the current activities of the subcommittee and discuss our direction for the future.

1. DEI Panelist 1
***Devin Abellon, P.E., Member**, Uponor, Centennial, CO*

2. DEI Panelist 2
***Art Giesler, Member**, PermAlert, Niles, IL*

3. DEI Panelist 3
***Madison Schultz, P.E., Member**, OK BeCo, Oklahoma City, OK*

4. DEI Panelist 4
***Adrienne Thomle**, Honeywell, Minneapolis, MN*

5. DEI Panelist 5
***Craig Wanklyn, P.E., Member**, Kansas State University, Manhattan, KS*

Wednesday, June 29

Wednesday, June 29, 8:00 AM - 9:30 AM

Panel 3 (Intermediate)

Can Connected Buildings Save the Grid?

Track: Connected Buildings, Connected Communities
Room: Provincial (2)
Sponsor: 1.9 Electrical Systems, 7.5 Smart Building Systems
Chair: Randall Higa, P.E., Member, Southern California Edison, Rosemead, CA

Managing building assets: HVAC systems, energy storage (TES, batteries, district energy), and on-site generation (including photovoltaic), can significantly enhance the building's resilience to adverse events and grid outages. Interconnecting buildings in microgrids or connected communities enables further sharing of the resilience benefits and can help stabilize the grid during emergencies. This session discusses how grid-connected buildings and communities (e.g., military bases, universities) can improve resilience. A key part of the session will be to solicit audience input metrics for defining, designing for, and optimizing resilience.

Learning Objectives:

1. Identify resilient buildings and systems
2. Develop more advanced Commissioning Plans for testing and verifying resilient building systems
3. Have an understanding of what building attributes are supportive of the electric grid.
4. Have an understanding of how good grid citizenship has changed over the past few decades.
5. Define Smart Grid functions, objectives and architecture
6. Describe how the Smart Grid affects building operations

1. What Makes a Resilient Building?
***Zachery DeLuke, P.E., Member**, Engineering Economics, Inc., Arlington, VA*

2. How Can Buildings be Better "Electric Grid Citizens"?
***Randall Higa, P.E., Member**, Southern California Edison, Rosemead, CA*

3. Military Lessons for Connecting the Dots from an Individual Building to the Interconnected Installation Community
***Frank Pucciano, Life Member**, Pucciano Energy Consultants, Lilburn, GA*

4. Resilience Benefits of Connected Buildings: What Are the Metrics of Building Resilience?
***Lawrence Markel, Fellow ASHRAE**, Oak Ridge National Laboratories, Knoxville, TN*

8:00 AM - 9:30 AM

Conference Paper Session 17

Residential Buildings: Case Studies, Data and Modeling

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Osgoode (LC)
Chair: Suzanne LeViseur, Haddad Engineering, Inc., Jacksonville, FL

Residential buildings represent nearly half of the building energy consumption in the United States. Therefore there is substantial need to improve residential building operation to reduce energy use and emissions. In this session, innovations in the modeling, performance, and assessment of performance of residential buildings is covered.

Learning Objectives:

1. State the impact of total external static pressure upon ECM power use.
2. Describe at least three factors that can be utilized to minimize total external static pressure.
3. Describe how different ventilation systems and elevator/stairwell door air tightnesses impact infiltration in high rise multi-unit residential buildings.
4. Describe how different ventilation systems and elevator/stairwell door air tightnesses impact intersuite air flow in high rise multi-unit residential buildings.
5. Describe recursive feature elimination as a feature selection algorithm.
6. Describe the most important features for virtual energy audits based on ERS approach

1. A Control Study of Residential Central Air Duct Design upon Static Pressure and Energy Consumption (TO-22-C063)
Charles Withers Jr. *and Eric Martin, FSEC Energy Research Center at the University of Central Florida, Cocoa, FL*

2. Investigation of Energy and Dehumidification Performance of Split Residential Air Conditioners among Different Fan Control Modes in Hot and Humid Climates (TO-22-002)
Gang Wang, P.E., Member[1]*, Li Ding*[1] *and Li Song, Ph.D., P.E., Member*[2]*, (1)University of Miami, Coral Gables, FL, (2)University of Oklahoma, Norman, OK*

3. Reducing Indirect Inter-Suite Air Flow in High-Rise Multi-Unit Residential Buildings: A Parametric Study Using a CONTAM Model (TO-22-C064)
Jamie Fine, Ph.D., Associate Member*, Cara H. Lozinsky and Marianne Touchie, Ph.D., P.E., Associate Member, University of Toronto, Toronto, ON, Canada*

4. Virtual Energy Auditing: A Data-Driven Model for Predicting EnerGuide Rating System (TO-22-C065)
Araz Ashouri, Ph.D.[1]*, Farid Bahiraei, Ph.D.*[1]*, Scott Shillinglaw*[1] *and Christopher McLellan*[2]*, (1)National Research Council Canada, Ottawa, ON, Canada, (2)Natural Resources Canada, Ottawa, ON, Canada*

8:00 AM - 9:30 AM

Seminar 40 (Advanced)

Chiller-Heater Systems Enabled by Compressors and Ice

Track: HVAC&R Systems and Equipment
Room: Dominion North (2)
Sponsor: 8.1 Positive Displacement Compressors, 6.9 Thermal Storage , 8.2 Centrifugal Machines
Chair: Haotian Liu, Ph.D., Purdue University, West Lafayette, IN
Chiller-heater systems are being designed to electrify heating in buildings. This session provides an overview of chiller-heater systems including compressors, chillers, systems, and storage. Speakers discuss: compressor types, critical characteristics, and limitations in heating applications; chiller types and features important to heat recovery, heat pump, and heating applications; chiller-heater system building load considerations, equipment sizing, configurations, redundancy, and strategies to address equipment limits; and means to enable heat recovery even when heating and cooling loads aren't coincident using thermal storage.

Learning Objectives:

1. Define the functions, architecture and characteristics for chiller-heater system
2. Describe how the chiller-heater system operates and interacts buildings
3. Provide an overview of chiller-heater system equipment and their associated limitations
4. Apply the technologies and strategies in chiller-heater system to speed up the electrification of heating in buildings
5. To explain the objectives of Electrification and give examples to demonstrate its value.
6. Show that with a thermal storage system in a building, “free cooling”, in seasons when heating is also needed, is actually wasting energy that could be stored and used the following day.
7. Water is a unique substance, that can store lots of energy in both of its changes of phase, at temperature close to idea.

1. Compressors in Heating Applications
Drew Turner*, Danfoss, Baltimore, MD*

2. Chillers in Heating Applications
Paul Kozlov*, Geoclima, Victoria, Australia*

3. Chiller-Heater System Considerations

***Charlie Marino, Associate Member**, AKF Group, New York, NY*

4. Electrification, Heat Pumps and Thermal Energy Storage: Using Yesterday's Waste Energy for Tomorrow's Heating
***Mark MacCracken, P.E., Member**, CALMAC Corp, Fair Lawn, NJ*

8:00 AM - 9:30 AM

Seminar 41 (Advanced)

Optimizing Smart Building Operation with Machine Learning

Track: Fundamentals and Applications
Room: Dominion South (2)
Sponsor: 1.13 Optimization, 1.4 Control Theory and Application
Chair: David Yashar, Ph.D., Member, National Institute of Standards and Technology, Gaithersburg, MD
This advanced session discusses sophisticated machine learning (ML) optimization techniques and their application to improve operational efficiency and delivery of services for complex systems such as buildings and campuses. This session includes three presentations that focus on Supervised Learning and Reinforced Learning techniques for driving building controls towards superior strategies.

Learning Objectives:

1. Describe machine learning and its potential application for smart building optimization
2. Compare the energy efficiency of ASHRAE Guideline 36 with that of the DRL-based control
3. Explain the potential of using machine learning for model predictive controls
4. Describe the difference between structured reinforcement learning and other RL approaches
5. Describe machine learning and its potential application for smart building optimization
6. Compare the energy efficiency of ASHRAE Guideline 36 with that of the DRL-based control
7. Describe the difference between structured reinforcement learning and other RL approaches
8. Understand current research questions in structured RL
9. Describe machine learning and its potential application for smart building optimization
10. Explain the potential use of machine learning for model predictive controls

1. A Comparison Study of ASHRAE Guideline 36 Supervisory Controls and Deep Reinforcement Learning-Based Controller for a Multi-Zone VAV System
***Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE**, Texas A&M University, College Station, TX*

2. Implementation of Structured Reinforcement Learning for Supply Air Temperature Control
***Amanda Pertzborn, Ph.D., Associate Member**, NIST, Gaithersburg, MD*

3. Supervised Learning: A Powerful Tool for Smart Building Optimization
***Omar Abdelaziz, Ph.D., Member**, Zewail City of Science and Technology, Giza, Egypt*

8:00 AM - 9:30 AM

Seminar 42 (Intermediate)

Turning Over a New Building Control System: Are You Smarter than a Fifth Grader?

Track: HVAC&R Systems and Equipment
Room: Grand East (LC)
Chair: Catherine Tinkler, Associate Member, Page Southerland Page, Inc., Houston, TX
Control systems that underperform are one of the worst problems a building can face. Recognizing that control design, installation and operation are not new to our industry, shouldn't we expect that all the rough spots have been worked out by now? Nevertheless, consistent forces in design, construction, and operations often produce the perfect storm for control catastrophes. This session identifies why control system turnover and operations are imperfect, what are the critical issues from the Owner's perspective, and what can be done to mitigate and ultimately avoid the pitfalls.

Learning Objectives:

1. Identify challenges/reasons why it is so hard to make a BAS work during construction and commissioning.
2. Highlight owner's mitigation strategies that can be done following turnover of a project.
3. Understand how trade coordination and scheduling as well as quality across all disciplines leads to a better controls system rather than letting time and cost drive the project.
4. Describe the characteristics of simple versus complicated/complex/chaotic building systems and the characteristics of thorough commissioning seen for each type.

5. Identify challenges/reasons why it is so hard to make a BAS work during construction and commissioning.
6. Highlight owner's mitigation strategies that can be done following turnover of a project
7. Understand how trade coordination and scheduling as well as quality across all disciplines leads to a better control system, rather than allowing schedule and cost drive the project.
8. Describe ASHRAE Guideline 36 and its general content.
9. Highlight the Owner's strategies that can be done following turn-over of the project.
10. Identify challenges/reasons why it is so hard to make a BAS work during construction and commissioning.

1. House-Training Your BAS Puppy: An Owner's Perspective on Why It Takes so Long, with so Much Effort to Get Your Control System up and Running
***Orvil Dillenbeck, P.Eng., Member**, Canadian Nuclear Laboratories, Chalk River, ON, Canada*

2. Turning over a New Building Control System: Driving Factors That Lead to Bad Controls
***Aaron Sorrell, Member**, General Services Administration, Boston, MA*

3. Control System Turnover: The Longest 3 Years of the Project
***Martin Weiland, P.E., Member**, US General Services Administration, Washington, DC*

8:00 AM - 9:30 AM

Seminar 43 (Intermediate)

Water Quality in Low Occupancy and Shutdown Buildings: Lessons Learned from COVID-19 Building Shutdowns

Track: Buildings in the Aftermath of COVID-19
Room: Sheraton C (LC)
Sponsor: 3.6 Water Treatment, 2.8 Building Environmental Impacts and Sustainability, TC 7.9
Chair: Tania Ullah, Associate Member, National Institute of Standards and Technology, Gaithersburg, MD
The COVID pandemic has had unprecedented and significant impacts on the global community. This session discusses the effects of building shutdowns during the last two years on plumbing systems and water quality. Speakers will address building operators, code officials, plumbing industry/manufacturers, and researchers on the valuable lessons learned during the pandemic. Specifically, speakers will share water quality data from during and after COVID building shutdowns, identify research gaps, and suggest ways in which current guidelines for building plumbing recommissioning can be improved.

Learning Objectives:

1. Explain why there was widespread concern over stagnation in building plumbing systems during COVID lockdowns
2. Describe lessons learned from building water testing studies
3. Quantify the potential short- and long-term impact of shock chlorination, flushing and superheating on the prevalence of Legionella in hot water systems
4. Explain practical research needs to effectively apply plumbing recommissioning protocols

1. Variable Legionella Response to Flushing after Moderate and Long-Term Plumbing Stagnation
***William Rhoads, Ph.D.**, Eawag, Dübendorf, MD, Switzerland*

2. Can Flushing, Superheating and Shock Chlorination Control Legionella after Extended Stagnation?
***Marianne Grimard-Conea** and Michele Provost, Ph.D., Polytechnique Montreal, Montreal, QC, Canada*

3. Plumbing Recommission Guidelines: Lessons from Water Testing during COVID Building Shutdowns
***Andrew Whelton, Ph.D.**, Purdue University, West Lafayette, IN*

Wednesday, June 29, 9:45 AM - 10:45 AM

Conference Paper Session 18

Moisture and Humidity Management in Commercial Buildings

Track: HVAC&R Systems and Equipment

NY PDH G

Room: Osgoode (LC)
Chair: John Dunlap, Fellow Life Member, Dunlap & Partners, Richmond, VA
There are many types of buildings where moisture and humidity management are critical. Moisture must be managed in order to maintain a healthy and comfortable indoor environment. In this session, projects and efforts to improve efficiency while also managing humidity and moisture sources are discussed.

Learning Objectives:

1. Understand the importance of and technologies that allow for the reduction of carbon emissions from controlled horticultural facilities.
2. Understand current and a potential future regulatory environment that can reduce carbon emissions from controlled horticultural facilities.
3. Understand how to properly calculate HVAC loads for a cannabis flowering room
4. Identify key considerations when sizing and selecting HVAC equipment for cannabis facilities
5. Understand the concept of multistage dehumidification
6. Give an overview of the desiccant concentration variation and its effect on the moisture removal
7. Give an idea regarding the influence of temperature on dehumidifier

1. Establishing Efficiency Criteria for Controlled Horticulture Facilities (TO-22-C066)
Diana Burk[1]*, Jim Edelson, Member*[1]*, Alexi Miller, P.E., Member*[1] *and Harold Jepsen, Member*[2]*, (1)New Buildings Institute, Portland, OR, (2)Legrand, Pleasant Grove, UT*

2. HVAC Design Considerations, Operations and Equipment Options for a Cannabis Grow Facility (TO-22-C067)
John G. Williams, Mehran Salehi, Ph.D., Associate Member*, Kathryn Lee, P.E., Associate Member, Amulya Surapaneni, Student Member and Sanaz Saadatifar, Harris Design Studio, Oakland, CA*

3. Influence of Desiccant Concentration and Temperature on Moisture Condensation Using Multistage Dehumidifier (TO-22-C068)
Shiva Kumar, Ph.D.[1] *and Sampath Suranjan Salins*[2]*, (1)Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, India, (2)Manipal University, Dubai, Dubai, United Arab Emirates*

9:45 AM - 10:45 AM

Seminar 44 (Basic)

Are all UV Wavelengths the Same: Emergence of Far UV and UV LEDs for Disinfection

Track: HVAC&R Systems and Equipment
Room: Dominion North (2)
Sponsor: 2.9 Ultraviolet Air and Surface Treatment
Chair: Ashish Mathur, Ph.D., UVDI, Valencia, CA
Not all UV wavelengths are the same. There are various wavelengths of UV light that can prove beneficial for some applications and may pose issues for others. This seminar discusses the various UV wavelengths that can be used for buildings and facilities and when to choose one wavelength over another for the desired results.

Learning Objectives:

1. Explain the salient aspects of UVC LED and FAR UV (222 nm) technology
2. Distinguish the essential differences between conventional UVC technology using low pressure mercury lamps from UVC LEDS and Far UV excimer lamps
3. Design disinfection solutions using UVC LEDs and filtered Far UVC lamps
4. Determine optimal applications for the use of UVC LEDs and Far UVC technology
5. Get a good understanding of the basics of Far UV-C
6. Explain basic terms of irradiance, dose and TLVs
7. Describe why filtered Far UV-C is human safe
8. Know about the application of Far UV-C in Air and Surface disinfection

1. Applications Using UVC LEDs: Leading the Way for an Effective Mercury-Free Future
Rajul Randive, Ph.D.*, Crystal IS, Green Island, NY*

2. Challenges and Opportunities for Filtered Far UV-C Disinfection Solutions in Occupied Spaces
Holger Claus, Ph.D.*, Ushio America, Cypress, CA*

9:45 AM - 10:45 AM

Seminar 45 (Intermediate)

Critical Ventilation in Critical Facilities: Demand Control Ventilation

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Dominion South (2)
Sponsor: 9.10 Laboratory Systems
Chair: Rachel Romero, P.E., Member, National Renewable Energy Laboratory, Golden, CO
People working in critical facilities, such as laboratories, depend on proper design and operation of the building systems to provide safe and controlled workspaces to support their scientific endeavors. It is critical to get the laboratory airflow control systems right. Air is the primary carrier of heat, moisture, contaminants, and airborne hazards in and around laboratory buildings. As a result, occupant safety is the main driver of laboratory ventilation system design and operation. In this presentation, attendees learn more about innovations in demand-controlled ventilation.

Learning Objectives:

1. Identify key elements of a Smart Lab
2. Describe the barriers to sensor technologies in lab spaces
3. Compare the effectiveness of estimating the hazardous exposure risk of several common lab situations based on lab occupant activities and proximity to hazardous material
4. Compare absolute versus differential measurement of chemical concentration for effectiveness in reducing risk of hazardous exposure
5. Describe how the occupant demand for ventilation helps to establish system design and operating specifications.
6. Determine how application of a risk assessment can identify areas of concern and determine appropriate ventilation design levels.
7. Identify key elements of a Smart Lab
8. Describe the barriers to sensor technologies in lab spaces

1. How the Demand for Ventilation Drives Safety and Energy Efficiency in Labs and Critical Workspaces
***Tom Smith, Member**, 3Flow, Cary, NC*

2. Cost-Benefit Approach to Design and Operation of Laboratory Demand Control Ventilation Systems
***Paul Fuson**, Siemens Building Technologies, Buffalo Grove, IL*

3. A Low-Cost Demand-Control Ventilation Protocol for Critical Facilities
***Amanda Kirkeby, Associate Member**, National Renewable Energy Laboratory, Golden, CO*

9:45 AM - 10:45 AM

Seminar 46 (Intermediate)

Securing BACnet Using Lessons and Techniques from the IT Industry

Track: Connected Buildings, Connected Communities
Room: Provincial (2)
Sponsor: 1.4 Control Theory and Application, SSPC 135
Chair: Carol Lomonaco, Member, Johnson Controls, Milwaukee, WI
As the BAS industry starts to deploy BACnet/SC (Secure Connect), implementing secure communications between BACnet devices, practitioners are working on the necessary standards, guidelines and technologies to make the whole BACnet system secure and interoperable with IT and CISO processes and best practices. This seminar provides important updates on this work and the plan to transition it to ASHRAE and BACnet International. You'll learn about why this project is critical to the future of building controls and how to plan BACnet implementations that will be secure, interoperable and manageable as products start to come to market.

Learning Objectives:

1. Describe the importance of cybersecurity in commercial BAS control systems
2. Describe the role of BACnet/SC in cybersecurity
3. Describe the management of future BACnet devices and systems
4. Describe the information that IT professionals need from BACnet systems to ensure cybersecurity compliance
5. After attending this session, the attendees will be able to describe the core principles behind the BAS Cybersecurity Roadmap.
6. After attending this session, the attendees will be able to describe the BAS Cybersecurity Acceleration program proposal.
7. Describe how BACnet/SC differs from BACnet/IP

8. Describe the management of future BACnet devices and systems under the Managed BACnet program
9. Describe the role of BACnet/SC in cybersecurity
10. Describe how BACnet/SC differs from BACnet/IP"

1. The Roadmap to a Fully Secure BACnet System
***Andy McMillan, P.E.**, BACnet International, Bedford, NH*

2. The Importance of Fully Adopting IT Industry Technologies and Best Practices
***James Lee**, Cimetrics, Inc., Boston, MA*

3. Planning for and Designing Cybersecure BACnet Projects
***Carol Lomonaco, Member**, Johnson Controls, Milwaukee, WI*

9:45 AM - 10:45 AM

Seminar 47 (Intermediate)

The ASHRAE Headquarters Building: Ensuring a Quality Occupant Experience while Working toward Net Zero Operation

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Sheraton C (LC)
Sponsor: Headquarters Building ad hoc, MTG for Effective Building Operations
Chair: Darryl Boyce, P.Eng., Fellow ASHRAE, ASHRAE, Kemptville, ON, Canada
The new ASHRAE Headquarters building is a 1970's era 66,000 sq. ft. building that has been renovated into an energy efficient, healthy indoor environment, net-zero energy facility. An integrated design was deployed to meet the owners project requirements (OPR) to achieve energy targets and deliver a comfortable and healthy indoor environment that facilitates occupant productivity. While the use of an existing building prevented significant waste, it also generated unique operational/integration challenges and opportunities to meet the ambitious OPR. This presentation focuses on strategies and technology platforms developed to ensure effective operations and a quality occupant experience.

Learning Objectives:

1. Describe the challenges of transitioning an effective design into effective and sustainable operations
2. Explain how technology can enhance building operations
3. Identify the critical design features that directly impact building operations
4. Define value creation opportunities associated with the inter-connectivity of the building technology systems
5. Engineers will be provided with information on the critical design features that directly impact building operations
6. Through this case study the attendees will be able to understand the challanges of transforming an effective design into effective and sustainable operations
7. Understand how contemporary building analytics work and future directions.
8. Understand some applications of building analytics on a high-performance building.
9. Trends driving Real Estate Digitization
10. The Power of IOT Data Platforms
11. Understanding multi stakeholder values

1. The ASHRAE Headquarters Building: Ensuring That High-Performance Design Strategies Are Managed to Drive Effective Operations and a Quality Occupant Experience I
***Darryl Boyce, P.Eng., Fellow ASHRAE**, ASHRAE, Kemptville, ON, Canada*

2. The ASHRAE Headquarters Building: Ensuring That High-Performance Design Strategies Are Managed to Drive Effective Operations and a Quality Occupant Experience II
***Jayson Bursill, Ph.D., Member**, Delta Controls Inc, Ottawa, ON, Canada*

3. The ASHRAE Headquarters Building: Ensuring That High-Performance Design Strategies Are Managed to Drive Effective Operations and a Quality Occupant Experience III
***Bill MacGowan, P.Eng.**, Cisco Systems Canada, Toronto, ON, Canada*

9:45 AM - 10:45 AM

Seminar 48 (Intermediate)

LIVESTREAM: Why You Shouldn't Lick Your Filter

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment
Chair: Jonathan Rajala, Ph.D., Member, AAF Flanders, Jeffersonville, IN
Air filters catch a lot of particles from simple dirt to microbes to bug parts. This seminar presents information on what filters actually catch and how that influences the air we breathe. The first presentation provides an overview of filter forensics: the extraction and analysis of dust on filters. The second shows a specific application to detecting SARS-CoV in air. The last presentation shows evidence of the variability of dust collected on HVAC filters. Filters protect us from pollutants in the air and we should definitely not lick them.

Learning Objectives:

1. Describe how filters have been used to explore indoor concentrations
2. Calculate indoor concentrations from filter dust and HVAC data
3. Describe what can you learn about the air you breathe from your filter dust
4. List what air filters capture, including very large particles
5. Describe how filters have been used to explore indoor concentrations
6. Calculate indoor concentrations from filter dust and HVAC data.
7. Describe what can you learn about the air you breathe from your filter dust.
8. List what air filters capture, including very large particles.
9. Describe how SARs-CoV-2 RNA may be measured using filter detection techniques
10. Define how filter forensics may be implemented in viral surveillance.

1. Quantitative Filter Forensics: From Filter Dust to Concentrations
Jeffrey Siegel, Ph.D., Fellow ASHRAE*, University of Toronto, Toronto, ON, Canada*

2. Estimating Indoor Airborne Concentration of Sars-Cov-2
Sarah Haines, Ph.D.*., University of Toronto, Toronto, ON, Canada*

3. Ick! I'm Glad I Didn't Breathe That! or What Does Your Air Filter Catch?
Carolyn Kerr, PhD

Wednesday, June 29, 11:00 AM - 12:30 PM

Panel 4 (Intermediate)

Occupant-Centric Building Operation: Insights from Building Operators across the World

Track: HVAC&R Systems and Equipment
Room: Provincial (2)
Sponsor: MTG.OBB Occupant Behavior in Buildings
Chair: Michael Kane, Ph.D., Member, Northeastern University, Boston, MA
Human behavior is known to significantly affect energy-use intensity of building systems. Most of the research on this topic has focused on the role of building occupants, while little has focused building operators: the humans tasked with the day-to-day monitoring, management, and maintenance of building HVAC systems in mid-sized and larger buildings. This seminar aims to shed light on the important role of operators and the technology they use in providing energy efficient occupant wellbeing. The insights presented come from the analysis and views of 72 structured interviews with building operators across seven countries, four continents, and four climate zones.

Learning Objectives:

1. Understand the contextual convergence of data from different parts of the built environment.
2. Utilization of IoT sensors, wearables, and other devices to capture occupant satisfaction information.

1. Objectivity and Opinion: Building Operators and Their Role in Occupant-Centric Building Operation
Michael Kane, Ph.D., Member*, Northeastern University, Boston, MA*

2. Getting Along: Challenges and Opportunities in Managing the Occupant, Operator Relationship
Krissy Govertsen, Associate Member*, Northeastern University, Boston, MA*

3. It Takes a Team: Roles, Responsibilities and Relationships in Building Monitoring, Management and Maintenance
Philip Agee, Student Member*, Virginia Polytechnic Institute and State University, Blacksburg, VA*

4. Drowning in Data: Occupant-Centric Building Operation with Sensors, Technology, Controls and Qualitative Data
Clayton Miller, Ph.D., Member*, National University of Singapore, Singapore, Singapore*

11:00 AM - 12:30 PM

Conference Paper Session 19

Heat Pump Innovations for Building Applications

Track: HVAC&R Systems and Equipment

Room: Osgoode (LC)
Chair: Michael Sherber, Plasma Air International, Inc., Stamford, CT

Heat Pumps are increasingly being used as a method of providing heating and cooling from electricity-based sources. In this session, various innovations and efforts that use heat pumps are discussed, including water-to-water heat pumps, transcritical carbon dioxide heat pumps, and heat pump hot water heaters.

Learning Objectives:

1. Describe the technology challenges with water-to-water heat pumps using the Stirling refrigeration cycle.
2. Name the advantages and disadvantages of the use of the Stirling refrigeration cycle for residential and commercial HVAC.
3. Identify the performance of the brazed plate heat exchanger in a CO2 heat pump water heater for domestic hot water and the space heating production.
4. Identify the effects of operating parameters on heat transfer of CO2 flowing in a tri-partite brazed plate gas cooler
5. Identify the main components of a geothermal heat pump.
6. Identify factors impacting the performance of a geothermal heat pump.
7. Design a Fault Detection and Diagnosis (FDD) procedure and compare different FDD techniques with several evaluation metrics
8. Understand the main FDD methods for residential Vapor Compression Cycle (VCC) systems
9. Describe differences in peak demand curtailment performance of grid-connected heat pump water heaters with and without advanced load up capability and compared to electric resistance water heaters, during typical Florida summer weather conditions.
10. Describe energy use savings or penalties associated with different control schemes of grid-connected heat pump water heaters with and without advanced load up capability, during typical Florida summer weather conditions.

1. Efficiency and Capacity Performance of a Stirling-Cycle Water-to-Water Heat Pump (TO-22-C069)
Stephen Kowalski, Member[1]*, Rusty Jewett*[2]*, Ahmad Abu-Heiba, Associate Member*[1]*, Kyle Gluesenkamp, Ph.D., Member*[1] *and Kashif Nawaz, Ph.D.*[1]*, (1)Oak Ridge National Laboratory, Oak Ridge, TN, (2)Sencera Energy, Inc., Charlotte, NC*

2. Experimental Study on Heat Transfer of Supercritical CO2 in a Tri-Partite Brazed Plate Gas Cooler (TO-22-C070)
Alireza Zendehboudi, Ph.D.[1]*, Zuliang Ye*[2] *and Armin Hafner, Dr.Ing.*[1]*, (1)Norwegian University of Science and Technology, Trondheim, Norway, (2)Xi'an Jiaotong University, Xi'an, China*

3. Sub-Slab Thermal Storage System for Coupling to a Heat Pump: Modelling Approach and Simulated Performance (TO-22-C071)
Luminita Dumitrascu, Student Member *and Ian Beausoleil-Morrison, Carleton University, Ottawa, ON, Canada*

4. Comparisons of Fault Detection and Diagnostic Methods for Residential Vapor Compression Cycle Systems (TO-22-C072)
Tao Yang, Student Member[1]*, Arkasama Bandyopadhyay, Ph.D., Associate Member*[1]*, Zheng O'Neill, Ph.D., P.E., Fellow ASHRAE*[1]*, Jin Wen, Ph.D., Member*[2] *and Austin Rogers, Ph.D., Affiliate*[3]*, (1)Texas A&M University, College Station, TX, (2)Drexel University, Philadelphia, PA, (3)Pacific Northwest National Laboratory, Richland, WA*

5. Detailed Evaluation of Electric Demand Load Shifting Potential of Heat Pump Water Heaters (TO-22-C077)
Karen Fenaughty[1]*, Danny Parker*[1]*, Josh Butzbaugh*[2]*, Rob Vieira*[1] *and Carlos Colon*[1]*, (1)FSEC Energy Research Center, Cocoa, FL, (2)Pacific Northwest National Lab, Richalnd, WA*

11:00 AM - 12:30 PM

Seminar 50 (Intermediate)

Design to Commissioning in Cleanrooms for Performance and Reliability

Track: HVAC&R Systems and Equipment
Room: Dominion South (2)
Sponsor: 9.11 Clean Spaces
Chair: Vincent Sakraida, P.E., Associate Member, PCI - Salas O'Brien, Evansville, IN
Cleanrooms are expensive to build and operate over their expected useful life. They are expected to be adaptable and reconfigurable. Commissioning and performance verification are the heart of "proof" proper space environmental conditions, whether for the chip inside a smart phone or pacemaker or sterility of a COVID-19 vaccine. The commissioning process verifies a cleanroom's performance and reliability. The objective of the commissioning process is to be in "Static balance and under dynamic control around the agreed design operating set points".

Learning Objectives:

1. Define the sequential steps to follow in designing a cleanroom
2. Apply the process for integrated commissioning to ensure cleanroom performance and reliability
3. Describe the shortcomings of room differential pressurization control and how to make corrective action to ensure stable space differential pressurization control
4. Explain the best practices to ensure cleanrooms are energy efficient and maintainable
5. Define the sequential steps to follow in designing a cleanroom Explain the best practices to ensure cleanrooms are energy efficient and maintainable
6. Apply the process for integrated commissioning to ensure cleanroom performance and reliability Describe the shortcomings of room differential pressurization control and how to make corrective action to ensure stable space differential pressurization control
7. Explain the value of design review
8. Describe the importance of well defined control sequences

1. Designing a Cleanroom HVAC System
***Yusuf Bhetasiwala, Member**, Encon Expertise Pvt. Ltd., Mumbai, India*

2. Overview of an Integrated Commissioning Process for Performance and Reliability
***Conor Murray**, ASHRAE Ireland, Dublin, Ireland*

3. Best Practices and Common Mistakes in Cleanroom Projects with a Focus on Energy and Ease of Maintenance
***Conor Murray**, ASHRAE Ireland, Dublin, Ireland*

4. Case Study on Managing Room Differential Pressure Control Using Venturi Valves
***Mike Amstadt, BCxP, Member**, Mead & Hunt, Middleton, WI*

11:00 AM - 12:30 PM

Seminar 51 (Intermediate)

Thermal Energy Storage Solutions for Buildings: Materials to Applications

Track: HVAC&R Systems and Equipment
Room: Sheraton C (LC)
Sponsor: 1.3 Heat Transfer and Fluid Flow, TC 6.9
Chair: Kashif Nawaz, Ph.D., Oak Ridge National Laboratory, Oak Ridge, TN
Latent Thermal Energy Storage (LTES) integrated HVAC equipment can promote a more efficient integration of renewable sources leading to a novel way of thinking for air conditioning and space heating. Such LTES can be often integrated in the form of thermochemical (TCM) or Phase Change Materials (PCM)-embedded heat exchangers. The seminar presents past and current work on TCMs and PCMs focusing on material selection criteria for heat pump water heaters, potential of TCM salt hydrates as multi-cyclic LTES, important design parameters for efficient multi-scale LTESs, and on key characteristics of used embedded heat exchangers designs and associated modeling challenges.

Learning Objectives:

1. Identify the difference between thermochemical and phase change storage materials for use with HVAC&R equipment.
2. Understand the potential, limitations, and workability of Thermochemical Salt Hydrates as a thermal energy storage material for buildings.
3. Understand the most important design parameters for efficient Latent Thermal Energy Storages.
4. Understand the challenges in modeling and optimization of PCM-embedded heat exchangers.
5. Identify the difference between thermochemical and phase change storage materials for use with HVAC&R equipment.

6. Understand the potential, limitations, and workability of thermal energy storage materials for buildings.
7. Understand the most important design parameters for efficient Latent Thermal Energy Storages.
8. Understand the challenges in modeling and optimization of PCM-embedded heat exchangers.
9. Scale effects on the study of latent TES

1. Selection of Phase Change and Thermochemical Materials for Heat Pump Water Heater Thermal Energy Storage Applications
***Joe Rendall, Ph.D.**, Oak Ridge National Laboratory, Oak Ridge, TN*

2. Stable Thermochemical Salt Hydrates for Energy Storage in Buildings
***Sumanjeet Kaur, Ph.D.**, Lawrence Berkeley National Laboratory, Berkeley, CA*

3. On the Design of Latent Thermal Energy Storage for Air Conditioning and Space Heating
***Simone Mancin, Ph.D.**, University of Padova, Padua, TN, Italy*

4. Review of Phase Change Material Embedded Heat Exchangers Used in Latent Thermal Storage Systems
***Vikrant Aute, Ph.D., Member**, University of Maryland, College Park, MD*

11:00 AM - 12:30 PM

Seminar 52 (Intermediate)

LIVESTREAM: Without Ventilation Effectiveness, Air Change per Hour Is Just a Number

Track: IAQ, Energy Use, Comfort and Health of Sustainable Buildings
Room: Grand East (LC)
Sponsor: MTG.ACR Air Change Rate, 9.10 Laboratory Systems, TC 9.6, TC 9.11
Chair: Roland Charneux, P.Eng., Fellow ASHRAE, Pageau Morel et Associés Inc., Montreal, QC, Canada
For a long time, air change per hour numbers have been used by designers of different types of buildings, labs, healthcare, cleanrooms, etc. Recent CFD analysis and tests showed that ACR does not guarantee the quality of the interior environments. The effectiveness of the ventilation in the room should be the main concern, but how to evaluate this ventilation effectiveness? The three speakers present their perspective related to the evaluation of the ventilation effectiveness.

Learning Objectives:

1. Describe how risk drives ventilation specifications such as air changes per hour
2. Explain how air tracers can be used to challenge and verify the effectiveness of ventilation systems to dilute and remove airborne contaminants under real-world conditions
3. Describe ISO 14644 Testing Requirements for Recovery Rates
4. Explain how CFD can be employed to estimate ventilation effectiveness
5. Understand how CFD can be employed to estimate ventilation effectiveness.
6. Understand the importance of airflow patterns on ventilation effectiveness.
7. Describe how airflow patterns affect contaminant dilution and removal from a space.
8. Understand the use of air tracers to measure concentration accumulation and decay as function of the air change rate and prevailing airflow patterns.

1. A Computational Fluid Dynamics Approach for Evaluation of Ventilation Effectiveness
***Kishor Khankari, Ph.D., Fellow ASHRAE**, AnSight LLC, Ann Arbor, MI*

2. Risk-Based Methods to Specify and Test Effectiveness of Air Change Rates in Labs and Critical Workspaces
***Thomas Smith, Member**, Henderson Engineers, Lenexa, KS*

3. Cleanroom Ventilation Effectiveness and Recovery Rates per ISO 14644
***Phil Naughton, Life Member**[1] and Yusuf Bhetasiwala, Member[2], (1)EcoCleanroom HVAC consulting, Austin, TX, (2)Encon Expertise Pvt. Ltd., Mumbai, India*