

## Table of Contents

Tool for Energy Efficient Building Envelope Retrofitting <i>Bandana, Jha; Bishwajit, Bhattacharjee</i>	1
Rapid Modeling of Large and Complex High Performance Buildings Using EnergyPlus <i>Sagar, Rao; David, Conant-Gilles; Yiyuan, Jia; Brittany, Carl</i>	9
EnergyPlus Interior Radiant Heat Exchange Runtime Performance Improvements <i>Joshua, New; Mark, Adams</i>	17
Do Office Buildings 'Save' Energy in the United States Due to Daylight Saving Time (DST)? a 50-State Simulation-Based Study <i>Tarek, Rakha; Yuanyue, Chen; Christoph, Reinhart</i>	21
State of the Industry – Computer-Aided Simulation of High-Performance Building Enclosures <i>Sarah, Rentfro; Anthony, Nicastro</i>	29
Model-Based Estimation of Building Infiltration <i>Zhengwen, Hao; Zheng, O'Neill</i>	37
National Impact of ANSI/ASHRAE/IES Standard 90.1-2016 <i>Bing, Liu; Michael, Rosenberg; Rahul, Athalye</i>	45
A Simplified Energy Modeling Approach for Buildings <i>Chris, Baker Supriya, Goel Nora, Wang Michael, Rosenberg Doug, Wolf Paul, Henderson</i>	53
Comparative Analysis of Machine Learning Algorithms for Building Archetypes Development in Urban Energy Modeling <i>Usman, Ali Mohammad Haris, Shamsi Fawaz, Alshehri Eleni, Mangina James, O'Donnell</i>	60
Profiling Occupancy Patterns in Community-Scale Residential Buildings Using Measured Energy Use Data Clustering <i>Rawad, El Kontar; Tarek, Rakha</i>	68
Estimating Window Dimensions of Residential Buildings in District Energy Models <i>Ina, De Jaeger; Yixiao, Ma; Dirk, Saelens</i>	76
An Intelligent Knowledge-Based Energy Retrofit Recommendation System for Residential Buildings at an Urban Scale <i>Usman, Ali Mohammad Haris, Shamsi Cathal, Hoare Eleni, Mangina James, O'Donnell</i>	84
Development of the Urban Surface Management Software for PVs and Stormwater with Connectivity to Urban Modeling Interface <i>Jung Min, Han; Christoph, Reinhart</i>	92
Modeling Building Energy Performance in Urban Context <i>Tianzhen, Hong; Xuan, Luo</i>	100
A Gaze Visualizer Tool Implementation of Gaze Data into Lighting Rendering Tools Using Radiance and Honeybee for Grasshopper3D <i>Mandana Sarey, Khanie Susanne, Kjaergaard Mia, Johnsen Kristoffer, Negendahl Jan, Wienold Maryline, Andersen</i>	107
Changing California Code: Finding the Next Savings Opportunities <i>Stefan, Gracik; Jared, Landsman; Ryan, Sit; Ken, Takahashi</i>	113
Computing Long-Term Daylighting Simulations from High Dynamic Range Imagery Using Deep Neural Networks <i>Yue, Liu; Alex, Colburn; Mehlika, Inanici</i>	119

Hybrid Simulation for Daylighting of Complex Fenestration Systems for Building Envelopes <i>Kemal, Celik; Alex, Mead; Khalid, Mosalam</i>	127
Development of a Comparison-Based Control Strategy of Electrochromic Glazing for the Management of Indoor Lighting and Energy Efficiency <i>Maryam, Hamidpour; Vincent, Blouin</i>	133
Modeling an Electrochromic Window Using a Multi-Criteria Control Strategy <i>Ranojoy, Dutta</i>	149
Influence of External Shading on Convective Heat Transfer Coefficient for a High-Rise Building <i>Meseret, Kahsay; Girma, Bitsuamlak; Fitsum, Tariku</i>	165
Comparative Analysis of White-, Gray- and Black-Box Models for Thermal Simulation of Indoor Environment: Teaching Building Case Study <i>K., Arendt; M., Jradi; H., Shaker; C., Veje</i>	173
A New Modeling Approach for the Assessment of the Effect of Solar Radiation on Indoor Thermal Comfort <i>Andrea, Zani Andrea, Mainini Juan, Blanco Cadena Stefano, Schiavon Edward, Arens</i>	181
Prediction of Improved Occupant's Thermal Comfort with Ceiling Fan through Coupled Energy Simulation and Computational Fluid Dynamics <i>Brijesh, Pandey; Atul, Sharma; Rangan, Banerjee</i>	189
Transient 3-D Modelling of Ceiling Fan for Achieving Thermal Comfort <i>Y., Anand; S., Verma; S., Anand</i>	197
Case Study of Occupant's Perception of Indoor Thermal Conditions under Different Heating Systems <i>Alžběta, Kohoutková; Jana, Horváthová; Martin, Kny; Ondřej, Nehasil</i>	205
The Development of an Indoor Environmental Monitoring Framework for Post-Occupancy Evaluation Using Real-Time Web-Tools <i>Nada, Tarkhan</i>	213
Glazing in Commercial Buildings - The Balance Between Cost and Energy Consumption <i>Jennifer, Williamson; Tat, Fu; Brent, Gabby; Jenna, Testa; Chen, Hu</i>	221
The Role of Space Design in Prediction of Occupancy in Multi-Functional Spaces of Public Buildings <i>Elham, Delzende; Song, Wu; Rima, Alaaeddine</i>	229
Exploring Geometric Sensitivity Using Rapid Energy Performance Simulation <i>Timothy, Hemsath; Joel, Yow</i>	237
Modeling Natural Ventilation in Early and Late Design Stages: Developing the Right Simulation Workflow with the Right Inputs <i>Maria Alejandra, Menchaca Brandan; F., Dominguez Espinosa</i>	242
Modeling of Connected Community Infrastructures Accounting for the Interdependencies Among Energy, Transportation, and Communication Networks <i>Xing, Lu; Yangyang, Fu; Wangda, Zuo</i>	250
Exploring Thermal Comfort Acceptance Criteria in Energy Modeling <i>Elvin, Ruya; Godfried, Augenbroe</i>	258
A Calibration and Adjustment Method for a Dynamic Visual Comfort Assessment <i>Zahra, Hamedani Ebrahim, Solgi Henry, Skates Mandana Sarey, Khanie Ruwan, Fernando</i>	266

<b>Aeroacoustic Facade Noise: Predicting Wind-Induced Noise from Perforated Facade Panels</b>	274
<i>Nathaniel, Jones; Alexej, Goehring</i>	
<b>Considerations for the Design and Energy Modeling of New Commercial Buildings with Increased Ventilation Rates</b>	282
<i>Caroline, Fluhrer Traube; Skander, Spies</i>	
<b>Assessing Indoor Concentrations of Formaldehyde in Single-Detached Canadian Households Due to Oriented Strand Board (OSB) Wall Sheathing</b>	290
<i>Matthew, David Baffa; David, Raymond Wach</i>	
<b>Development of an Empirical Method for Calculating Discharge Coefficients for CONTAM Models</b>	298
<i>Hao, Zhou; Yichun, Huang; Gavin, Xue; Chen, Chen</i>	
<b>Scripting Frameworks for Enhancing EnergyPlus Modeling Productivity</b>	312
<i>Amir, Roth Jamie, Bull Scott, Criswell Peter, Ellis Jason, Glazer</i>	
<i>David, Goldwasser Neal, Kruis Andrew, Parker Santosh, Philip David, Reddy</i>	
<b>EnergyPlus Performance Improvements via JSON Input Refactoring</b>	320
<i>Joshua, New; Mark, Adams</i>	
<b>SimulatorToFMU: A Python Utility to Support Building Simulation Tool Interoperability</b>	325
<i>Thierry, Nouidui; Michael, Wetter</i>	
<b>Integration of CFD Simulations in Computational Design for Harnessing the Natural Ventilation Performance of Typical Atrium Spaces in Athens, Greece</b>	331
<i>Angelos, Chronis; Fotini, Stefopoulou; Katherine, Liapi</i>	
<b>An Interactive Visualization Tool for Large-Scale Building Stock Modeling</b>	338
<i>Eric, Wilson; Noel, Merket</i>	
<b>Visualization of CFD Simulation Results in VR Environment for Design Feedback</b>	346
<i>Charles Steven, Sanchez; Xiaoqin, Zhang</i>	
<b>Reading and Writing Standardized HVAC Performance Data: An Early Implementation of ASHRAE Standard 205P</b>	352
<i>Neal, Kruis; Charles, Barnaby</i>	
<b>How to Improve ASHRAE 55 and Make It More Relevant</b>	359
<i>Andrew, Corney; Vladimir, Bajic</i>	
<b>A Detailed Methodology for Cloud-Based Daylight Analysis</b>	367
<i>Kerger, Truesdell; Andrew, Corney; Vladimir, Bajic</i>	
<b>Integration of Environmental Simulation to Parametric Design Workflow: Thermal Comfort and Daylight</b>	374
<i>JeeEun, Lee; Mingbo, Peng; Shin-yi, Kwan</i>	
<b>Daylighting and Energy Simulation Workflow in Performance-Based Building Simulation Tools</b>	382
<i>Ladan, Ghobad</i>	
<b>Integrating CFD with BEM in Early Design Stage to Optimize Design Solutions</b>	390
<i>Sedighehsadat, Mirianhosseinabadi; Mohit, Mehta; Jamy, Bacchus</i>	
<b>An Experimental and Numerical Model of a Solar Facade Prototype with Transparent Insulation and Selective Absorber</b>	398
<i>Miroslav, Čekon; Josef, Plášek; Richard, Slávik; Tomáš, Fečer; Peter, Juráš</i>	
<b>Model-Based Coupling of Air and Hydronic Systems Operation in a Typical Classroom of a High-Performance Academic Building</b>	406
<i>Seyed Arman, Mottaghi; Rodrigo, Mora</i>	

<b>Building Integrated Cogeneration System Design Sizing and Analysis for Climate Disruption</b>	414
<i>Thomas, Zakrzewski; Brent, Stephens</i>	
<b>Advances in Calibration of Building Energy Models to Time Series Data</b>	422
<i>David, Goldwasser; Brian, Ball; Amanda, Farthing; Stephen, Frank; Piljae, Im</i>	
<b>Experimental Calibration of a One-Dimensional Model for Simulating the Dynamic Thermal Behaviour of Stratified Lakes</b>	430
<i>Freek, Van Riet; Ruben, De Wolf; Ivan, Verhaert</i>	
<b>Modelica Models for Data Center Cooling Systems</b>	438
<i>Yangyang, Fu; Michael, Wetter; Wangda, Zuo</i>	
<b>Calibrated Simulation Modeling for Performance Analysis in BCVTB Platform</b>	446
<i>Yeo Beom, Yoon; Sedighehsadat, Mirianhosseiniabadi; Suwon, Song; Soolyeon, Cho</i>	
<b>Implications of EPBD Compliant Facade on Primary Cooling Energy Demand in Central Europe: Theory vs. Practice</b>	454
<i>Javed, Iqbal; James, Dirkes; Reith, Andras</i>	
<b>Quantifying the Reduction in Cooling Energy Due to Passive Cooling Techniques for Indian Cities</b>	462
<i>Arjun, Desai; Prasad, Vaidya</i>	
<b>Deep Energy Retrofit vs Improving Building Intelligence – Danish Case Study</b>	470
<i>Muhyiddine, Jradi; Christian, Veje; Bo, Nørregaard Jørgensen</i>	
<b>Technical and Economic Assessment of a Danish Public School Energy Renovation Using Dynamic Energy Performance Model</b>	478
<i>Muhyiddine, Jradi; Christian, Veje; Bo, Nørregaard Jørgensen</i>	
<b>Effects of Shading on the Energy Consumption of High-Rise Office Buildings in Hong Kong</b>	486
<i>Cong, Yu; Wei, Pan</i>	
<b>External Shadings Effect on Operating Energy Based on LCEA, Case Study: A Residential Building in Tehran</b>	494
<i>Nasim, Eslamirad; Mohamadjavad, Mahdavinejad</i>	
<b>Performance Evaluation and Optimization of Ventilated Double Skin Facade in China</b>	502
<i>Hao, Zhou; Chenguang, Xiong; Yichun, Huang</i>	
<b>Development of a Method for Selection of Representative City in a Climate Zone</b>	510
<i>Mayank, Bhatnagar; Jyotirmay, Mathur; Vishal, Garg; Javed, Iqbal</i>	
<b>A New Method for Determining Sub-Hourly Solar Radiation from Hourly Data</b>	518
<i>Timothy, McDowell; Samuel, Letellier-Duchesne; Michaël, Kummert</i>	
<b>Energy Model Calibration for Campus Office Buildings</b>	526
<i>Bo, Lin; Zhao, Chen</i>	
<b>Energy Modeling and Calibration of a Mixed-Use Building with Laboratories, Offices and Classrooms</b>	534
<i>Liu, Liu; Zhengwen, Hao; Fuxin, Niu; Zheng, O'Neill</i>	
<b>Calibration of a Building Energy Performance Simulation Model via Monitoring Data</b>	542
<i>Başak, Güçyeter</i>	
<b>Energy Modeling of Multi-Storied Residential Buildings – a Manual Calibration Approach</b>	550
<i>Shailza</i>	

<b>Building Energy Model Calibration: A Case Study Using Computational Fluid Dynamics with Air Leakage Testing and On-Site Weather Data</b>	558
<i>Tat, Fu; Edward, Lyon</i>	
<b>A Quicker Method for Determining the UA-Value of a Residential Building</b>	565
<i>Tony, Chen</i>	
<b>Development of a Baseline Building Model of Auto Service and Repair Shop</b>	573
<i>Yunyang, Ye; Gang, Wang; Wangda, Zuo; Peilin, Yang; Joshi, Keya</i>	
<b>Modeling Mission Critical Facilities for LEED: Lessons Learned</b>	581
<i>Kristopher, Baker; Xun, Jia</i>	
<b>Investigating the Impact of Cost-Based and Carbon-Based Renewable Energy Generation and Storage Sizing Strategies on Carbon Emissions for All-Electric Buildings</b>	588
<i>Rushil, Desai; Shivani, Shah; Shreshth, Nagpal</i>	
<b>Peak Load Reduction of District Heating by Control of Indoor Public Swimming Pool</b>	594
<i>Ok, Kim; Michael, Dahl Knudsen; Steffen, Petersen</i>	
<b>Refining Energy Model Data to Develop a Narrative: Guidelines for Effective Visual Communication</b>	600
<i>Ivan, Jose; Caroline, Traube; Skander, Spies</i>	
<b>Ground Source Heat Pump with Horizontal Ground Buried Pipes: Modelling and Optimization with TRNSYS</b>	607
<i>Gaoyang, Hou; Hessam, Taherian</i>	
<b>Investigation and Evaluation of a Horizontally Bored Geothermal Heat Pump System Used in the Cold Climate of the U.S</b>	615
<i>Rui, Miao; Yao, Yu; Rick, Audette</i>	
<b>Performance of Heat Pump Assisted Building-Integrated Combined Photovoltaic Thermal Solar Collectors (BiPVT) in Cold Climate</b>	623
<i>Khem Raj, Gautam; Grom Bruun, Andresen</i>	
<b>An Analysis on the Thermal Performance of a Horizontal Earth Tube System</b>	631
<i>Hoda Barzegar, Ganji; Dennis Michael, Utzinger; Kevin, Renken</i>	
<b>Integrating Modeling and Simulation Tools with Learnings from Nature: A Methodology for Form Generation By Emulating the Constructal Law of Nature</b>	639
<i>Mehdi, Azizkhani; Juan-Carlos, Baltazar</i>	
<b>Evaluating the Multi-Objective Optimization Methodology for Performance-Based Building Design in Professional Practice</b>	646
<i>Xiaofei, Shen; Aman, Singhvi; Andrea, Mengual; Maria, Spastri; Victoria, Watson</i>	
<b>Using Digitalization for More Reliable and Less Expensive Building Performance Analysis</b>	654
<i>Christoph, Maurer; Helen, Rose Wilson; Dragan, Curcija; Tilmann, Kuhn</i>	
<b>Outdoor Comfort Simulation of Complex Architectural Designs: A Review of Simulation Tools from the Designer Perspective</b>	659
<i>Emanuele, Naboni; Coccolo, Silvia; Marco, Meloni; Jean-Louis, Scartezzini</i>	
<b>Combined Ontology-Driven and Machine Learning Approach to Monitoring of Building Energy Consumption</b>	667
<i>Parastoo, Delgoshaei; Mohammad, Heidarinejad; Mark, Austin</i>	
<b>A Deep Reinforcement Learning Approach to Using Whole Building Energy Model for HVAC Optimal Control</b>	675
<i>Zhiang, Zhang Adrian, Chong Yuqi, Pan Chenlu, Zhang Siliang, Lu Khee Poh, Lam</i>	

<b>Adaptive Multi-Agent Control of HVAC Systems for Residential Demand Response Using Batch Reinforcement Learning</b>	683
<i>José, Vázquez-Canteli; Stepan, Ulyanin; Jérôme, Kämpf; Zoltán, Nagy</i>	
<b>Analaysis of a Large-Scale Database for Energy Performance Modeling of Existing Buildings</b>	691
<i>Hye Gi, Kim; Jae Eun, Sung; Sun Sook, Kim</i>	
<b>An Open Science Approach for Building Performance Studies</b>	699
<i>Steven, Firth; Gareth, Cole; Tom, Kane; Farid, Fouchal; Tarek, Hassan</i>	
<b>Reduced-Order Energy Modeling in Retro-Commissioning: A Case Study of an Academic Building</b>	707
<i>Saber Khoshdel, Nikkho; Jeff, Steffensen</i>	
<b>Influence of Plug and Process Loads and Occupancy on Ultimate Energy Savings – a New Approach</b>	713
<i>Roger, Chang; Drury, Crawley</i>	
<b>Optimal Strategy for Demand Charge Reduction in an Office Building under Different Rate Structure</b>	721
<i>Yuna, Zhang; Godfried, Augenbroe</i>	
<b>A Control-Oriented Building Envelope and HVAC System Simulation Model for a Typical Large Office Building</b>	729
<i>Sen, Huang; Yan, Chen; Paul, Ehrlich; Draguna, Vrabie</i>	
<b>A Pseudo-Transient Method for Modeling Flow Networks</b>	737
<i>Aaron, Powers</i>	
<b>Challenges and Opportunities in Whole Building Water Modeling</b>	743
<i>Fred, Betz; Lyle, Keck</i>	
<b>Unpacking Mid-Season Heating Demand in Social Housing</b>	751
<i>Victoria, Aragon Julian David, Quintero Stephanie, Gauthier Patrick, James Abubakr, Bahaj</i>	
<b>Dehumidification Strategies and their Applicability Based on Climate and Building Typology</b>	759
<i>Jagan, Pillai; Rushil, Desai</i>	
<b>Heat and Mass Transfer Analysis of the Micro-Porous Membrane/Phase Change Material Based Energy Recovery Ventilator</b>	767
<i>Mohammed Salman, Mohiuddin; Weihuan, Zhao</i>	
<b>OpenBuildingControl: Modeling Feedback Control as a Step Towards Formal Design, Specification, Deployment and Verification of Building Control Sequences</b>	775
<i>Michael, Wetter; Jianjun, Hu; Milica, Grahovac; Brent, Eubanks; Philip, Haves</i>	
<b>Sensitivity of Low-Voltage Grid Impact Indicators to Weather Conditions in Residential District Energy Modeling</b>	783
<i>Christina, Protopapadaki; Dirk, Saelens</i>	
<b>Characterizing Electric Grid System Benefits of MPC-Based Residential Load Shaping</b>	791
<i>Robert, Cruickshank; Anthony, Florita; Gregor, Henze; Charles, Corbin</i>	
<b>Digital Twins for Efficient Modeling and Control of Buildings an Integrated Solution with Scada Systems</b>	799
<i>Achin, Jain; Derek, Nong; Truong, Nghiem; Rahul, Mangharam</i>	
<b>A Bluetooth Based Occupancy Detection for Buildings</b>	807
<i>June Young, Park; Thomas, Dougherty; Zoltan, Nagy</i>	

A Test Cell to Infer Thermal Response of Building Components for Model Predictive Control Using Building Automation Sensors	815
<i>Elizabeth, LeRiche; J., McArthur</i>	
A Simulation Based Approach for Impact Assessment of Physical Faults: Large Commercial Building HVAC Case Study	823
<i>Yan, Chen; Sen, Huang; Draguna, Vrabie</i>	