EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 66

Definition and Simulation of Occupant Behavior in Buildings

Operating Agents

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Annex 66 Overview

Worldwide, occupant behavior (OB) is recognized as one of the key little-understood factors influencing variation in building performance (occupant comfort and energy consumption). Over the last decade, an over increasing number of scientific research has been addressing the topic of energy-related occupant behavior in buildings. This trend indicates the large growing interest among the research arena towards the discovery of a new branch of behaviorally driven energy efficiency conceptualization in the building sector. Since 2013, the International Energy Agency Annex 66 "Definition and Simulation of Occupant Behavior in Building," is moving significant steps to develop an integrative research arena, which is international and multidisciplinary. Two recent Expert Meetings in the Working Phase have been organized and hosted at the Vienna University of Technology in Vienna, Austria (March 30 – April 1st, 2016) and at the Carlton Univeristy in Ottawa, Canada (August 3rd – 5th, 2016). Presenters from more than 22 countries having broad backgrounds (engineering, architecture, psychology, sociology, marketing, researchers, and practitioners) participated in the expert meetings and symposium, positively stimulated discussions and debate to encourage contributions to Annex 66 activities.

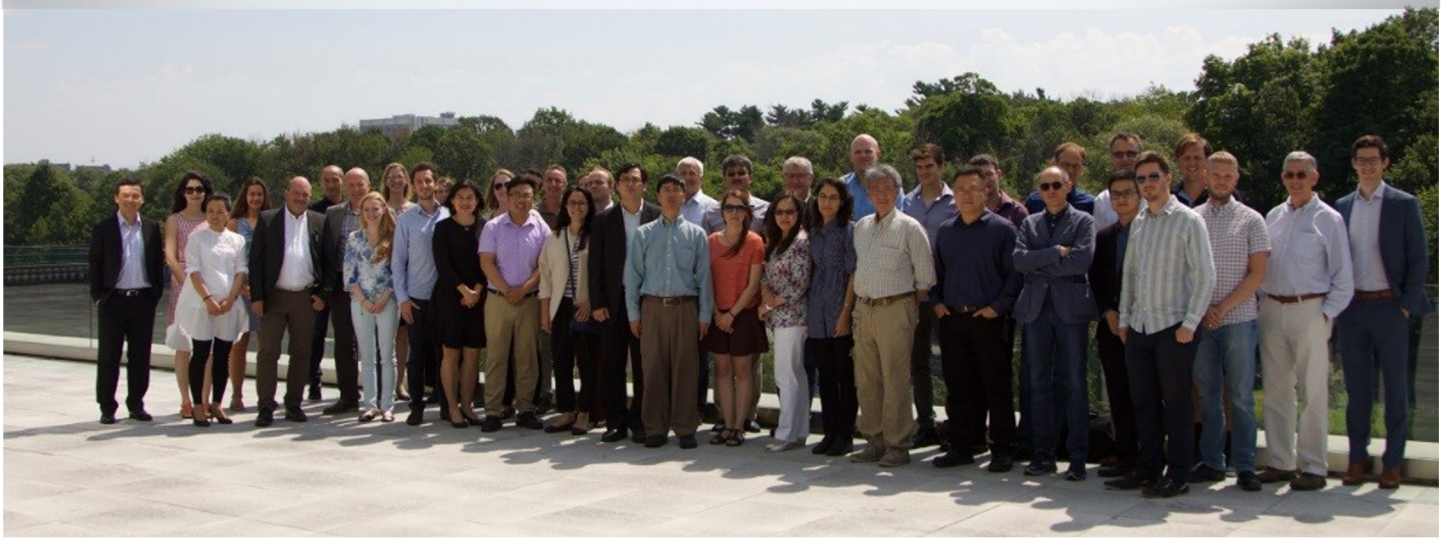
Group photo of the participants of the Annex 66 3rd Experts Meeting
April 2016 at TU Wien, Vienna, Austria

Overview of Annex 66

Key research activities are making real progress, including:

- Compilation of a comprehensive literature database on occupant behavior in buildings. The database is available at annex66.org web site;
- Development of a guidebook on behavior monitoring and data collection;
- Release of three OB modeling tools to improve building simulation;
  - the Occupancy Simulator (http://occupancysimulator.lbl.gov/)
  - the Occupant Behavior XML (obXML) Schema (behavior.lbl.gov)
  - the Occupant Behavior Functional Mockup Unit (obFMU) (behavior.lbl.gov)
- An international survey to research on human-building interaction in office buildings;
- Case studies to demonstarte and quantify the impact of occupant behavior on building energy performance;
- Methods to evaluate OB models;
- A fit-for-purpose methodology to select OB models to adapt to application needs;
- Reviews of OB modeling approaches, OB model representation and implementation in building performance simulation programs;
- Guideline on application of OB models and interpretation of results.

Group photo of the participants of the 4th Experts Meeting in Ottawa



The Annex 66 community continues to publish research outcomes in peer-reviewed journal articles. Five Special Issues are being organized to describe and publish the results of the Annex 66 occupant behavior research among the building science research community. Educational outcomes of the research activities include the organization of summer schools for graduate students, e.g., the "Dynamic Calculation Methods For Building Energy Assessment" successfully held at the Danish Technology University.

Going forward, efforts to strengthen and update multidisciplinary and international relationships and networks will be nurtured within the industry community, such as the ASHRAE Multidisciplinary Task Group on OB in Buildings (MTG.OBB), the IEA Task 24 project, and the U.S. National Science Foundation (NSF) Predictive Modeling Network for Sustainable Human-Building Ecosystems (SHBE). The final goal of these projects is to drive better empirical findings towards the development of market actions and international codes and standards.

The next steps of Annex 66 activities include wrapping up the major research activities and drafting chapters for the final report. The coming 5th Annex 66 Experts' Meeting and OB-17 Symposium will be held at Technical University of Denmark (DTU), Kgs. Lyngby, Denmark on May 17-19, 2017.

Subtask A:
Occupant movement and presence models in buildings

Leader: Andreas Wagner, Germany
Bing Dong, USA

This subtask aims at providing a description and simulation methodology for presence and movement of occupants in buildings. One further objective is to provide information on data collection about movement and presence in buildings. As a cross-sectional activity, the participants in Subtask A contribute to an occupancy monitoring guideline which covers the whole context of occupant behavior.

ACHIEVEMENT

• **A comprehensive literature review database:**
A large number of papers related to occupant behavior studies were collected on http://www.annex66.org/?q=biblio, up to 2016.

• **Occupant sensing devices and data collection technology:**
This task summarizes current occupancy sensing and data acquisition technologies for field applications focusing on both occupancy presence and interactions with the built environment. It intends to provide an overview and discussion platform of different current state-of-art technologies for researchers. Upon a comprehensive survey of the literature, methodologies of the occupancy data collection are categorized into six broad categories: image-based, threshold and mechanical, motion sensing, radio based environmental, person interactive and consumption sensing. The reviewed technologies include video cameras, infrared (IR) cameras, IR beam mechanisms, piezoelectric mats, reed contacts, door badge systems, passive infrared (PIR) sensors, ultrasonic Doppler sensors, microwave Doppler sensors, ultrasonic ranging sensors, ultra-wide band radios, GPS radios, WiFi / Bluetooth, radio-frequency identification (RFID), air property sensors, and acoustic sensors. All sensing technologies were evaluated against a list of performance metrics such as cost, sensing range, accuracy, deployment area, etc.

• **Modeling methods:**
More than 200 papers about the modeling techniques of building occupant presence and movement for performance-based building design and operation have been reviewed. This task aims to add integrative connections and distinctions among different modeling techniques and applications, which becomes increasingly indispensable for further development, validation and use of building occupancy models. For this purpose, the requirements of building design and operation applications are first reviewed, which determines the actual needs of building occupancy models. Second, mathematical methods, inputs, and outputs of the existing models for different applications are summarized. Third, trends and challenges in building occupancy modeling are discussed.

• **Occupancy monitoring guideline book:**
Together with other task leaders and contributors, the 1st draft of occupancy monitoring guideline book has been completed and internally reviewed. The objective of this book is guide researchers who are about to embark on an occupant research campaign. It introduces into fundamental questions about the topic and questions about developing an appropriate research and experimental design. Further, a comprehensive overview of sensors for monitoring environmental and also behavioral and action-related quantities is given, and different experimental environments (in-situ, laboratories) are introduced and discussed regarding their suitability for the respective research question. Additionally, data management is addressed as well ground truth, ethics, and privacy.

NEXT STEP

• **Writing final reports**: Subtask A will start drafting final reports including contents, major deliverables, methods, and outcomes.

• **Journal papers**: Subtask A plans to have several journal publications including occupant detection methods, review of occupant presence and movement, and modeling of occupant presence in residential and commercial buildings.

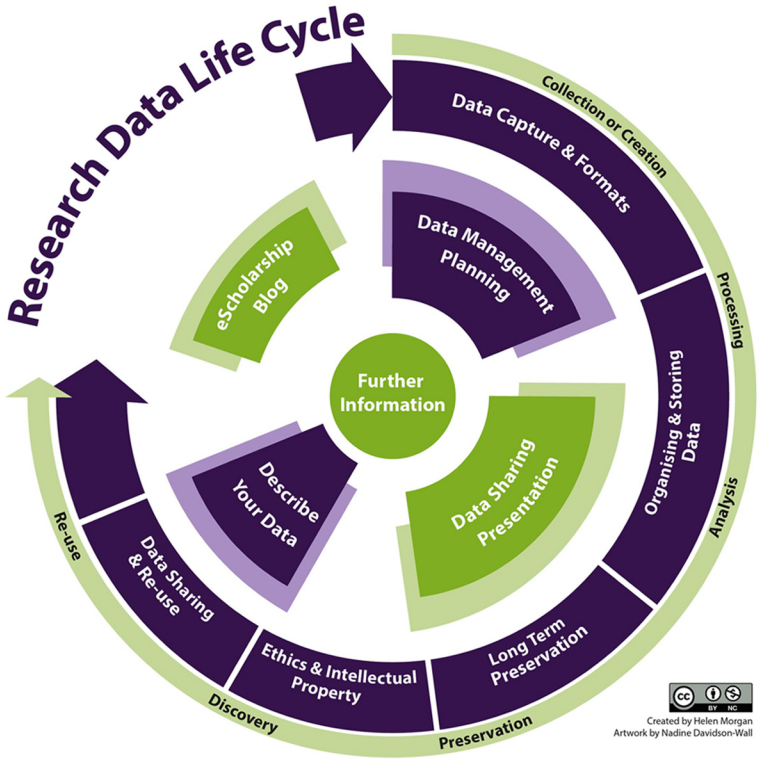
• **Book**: After an external review and a final revision the monitoring guideline book will be finished by the end of Summer 2017.

Subtask B:
Occupant action models in residential buildings

Leader: David Shipworth, University College London, UK
Henrik Madsen, Technical University of Denmark, Denmark

This subtask addresses the apparent lack of consistency in experimental design and modelling methodologies. Additionally the lack of availability of high quality data and access to algorithms or source code is addressed. This subtask coordinates efforts to lessen the severity of the above inconsistencies, with the spirit that models are supposed to be integrated into a coherent whole.

Scopes of Subtask B are as follow: Residential occupant modelling social network of who is doing what and how; State of the art in residential occupant modelling, following the path from presence, activities, behavior to comfort with thorough analysis; field survey and data management protocol for a good model; modelling strategies and validation techniques for a good model; use of the above to coordinate the filling of gaps between simulation and measurement; lighthouse contributions of new models and their applications during the Annex 66.



There are 5 Activities and Deliverables:
- Data collection methodology for residential occupant behaviors;
- Implementation of a central repository for occupant behavior data;
- Modelling methodology for occupant behavior in residential buildings;
- Methodology for residential occupant behavior methodology;
- Implementation of occupant behavior models in EnergyPlus.

ACHIEVEMENT

- **Special Issue:**
  A Special Issue of Nature Scientific Data is being organized to describe and publish several occupant behavior datasets.
- **Guidebook on stochastic modeling:**
  A guidebook on stochastic modeling is in-progress with an outline developed from contributions of the participants.
- **Summer School:**
  A Summer School on "Dynamic Calculation Methods For Building Energy Assessment," was successfully held at the Danish Technology University (DTU) on July 19 to 25, 2015. The main purpose of the summer school was to train the students in a methodology for evaluation of measured data. Statistical modeling methods for using such time series data are discussed to assess valuable information about the energy performance of a building or the building element. Invited lecturers include Hans Bloem (JRC, Ispra), María José Jiménez (CIEMAT), Henrik Madsen, Peder Bacher (DTU), Paul Strachan (Strathclyde University).
- **Outline:**
  An outline of the chapter for the final report was discussed at the Ottawa meeting.

Subtask C:
Occupant action models in commercial buildings

Leader: Ardeshir Mahdavi, TU Wien, Austria
Liam O'Brien, Carleton University, Canada

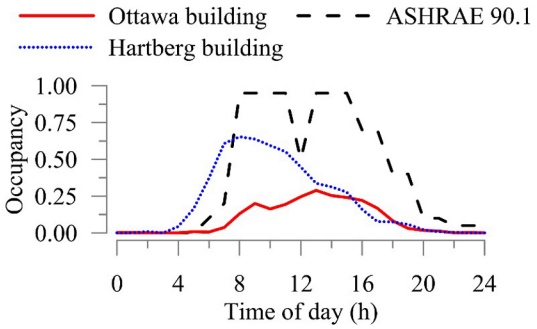
Subtask C focuses on monitoring, modeling, and simulating occupants in commercial buildings. The key research activities are both fundamental and applied. The researchers are interested in all occupant actions that occur in non-residential buildings, including but not limited to operable windows, window blinds, plug loads, lighting, and clothing level. In recognition of significant overlap between Subtask B (on occupants in residential buildings) and Subtask C, the members of the two subtasks have begun meeting, though the originally proposed activities remain the same. The main areas of interest within Subtask C include occupant model evaluation and validation, modeling occupant diversity, and model development.

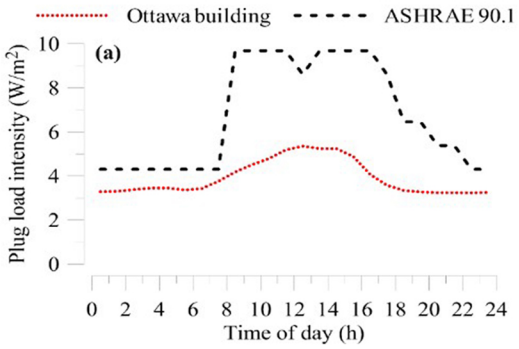
ACHIEVEMENT

Since beginning Annex 66 about two years ago the Subtask C members have made significant progress towards achieving the goals that were established at the beginning. Specifically, four primary activities were proposed, including:

- **Review of different modeling approaches for occupant behavior in buildings (D'Oca, Gunay, et al.)**

This activity is involved thoroughly reviewing existing modeling methods for modeling occupant behavior and actions and then testing them on several datasets. The scope of the models includes Bernoulli models, Markov Chains, and survival models. They were applied to lighting, plug loads, and occupancy data from a building in Canada and a building in Austria. The last part of the activity is a generalized discussion of the merits of the modeling forms and their applicability to various applications. The current status of this activity is that a manuscript is under review in the Journal of Building Performance Simulation. The corresponding models and code required to convert raw data to models will also be made public.

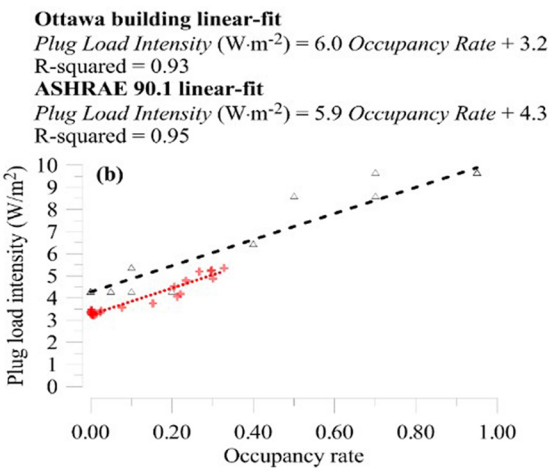




- **Approaches to address occupants' behavior diversity in model development (O'Brien, Mahdavi, et al.)**

The objective of this activity is to explore methods for modeling the diversity between occupants (with regards to presence and actions). The premise is that most current modeling approaches focus on developing a single model for typical occupants. However, this approach normally fails to reproduce the observed diversity and corresponding uncertainty of simulated occupants. To improve the state-of-the-art, a paper was written to evaluate three hypotheses using occupancy data from 16 offices. The hypothesis were:

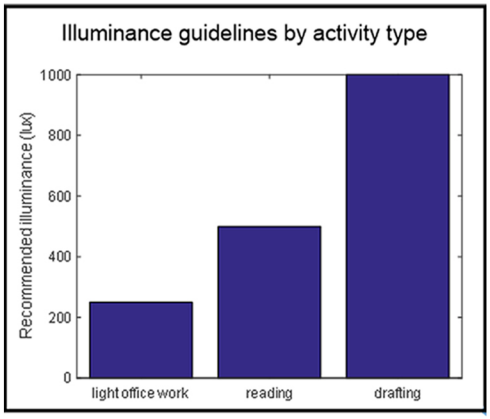
1. Occupant traits are best described by a continuous function; not discrete.
2. Modeling occupants from grouped occupant data suppresses population diversity.
3. Randomly selecting occupant traits to develop individual occupant models exaggerates population diversity.

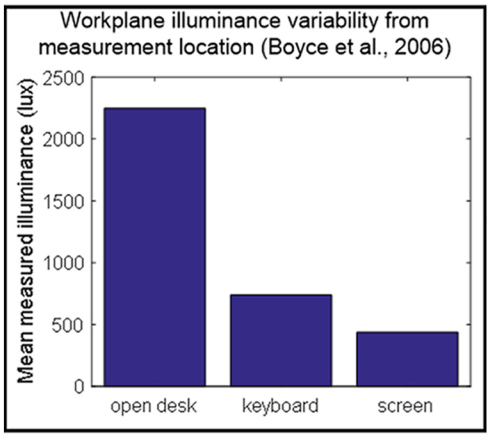


Subtask C:
Occupant action models in commercial buildings

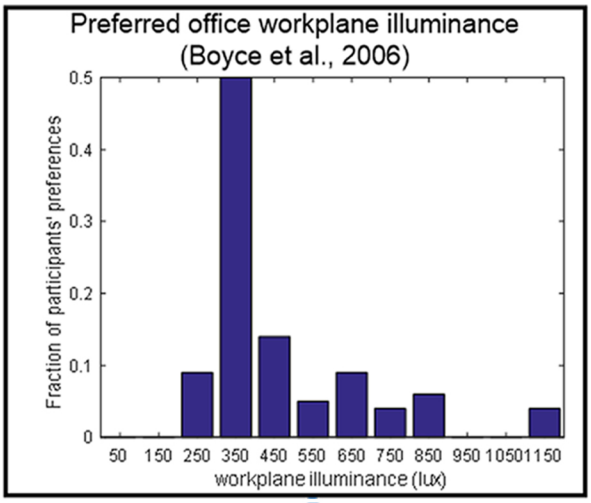
Leader: Ardeshir Mahdavi, TU Wien, Austria
Liam O'Brien, Carleton University, Canada

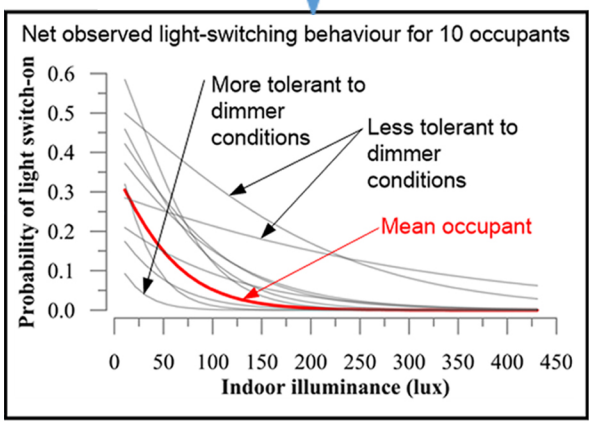
The results strongly suggest that current methods to model occupants significantly suppress diversity and then randomly selecting occupant traits within observed trait distributions can lead to unrealistic synthetic occupants. The status of this activity is that it has been submitted to a special issue on occupant modeling within the Journal of Building Performance Simulation.



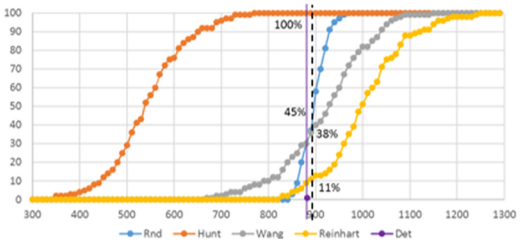


Other contextual factors
(e.g., O'Brien and Gunay (2014))

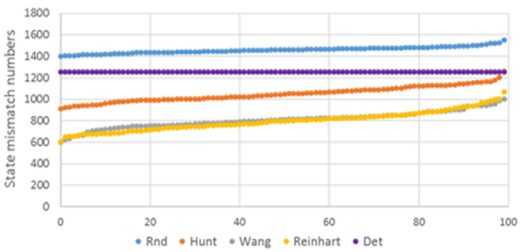




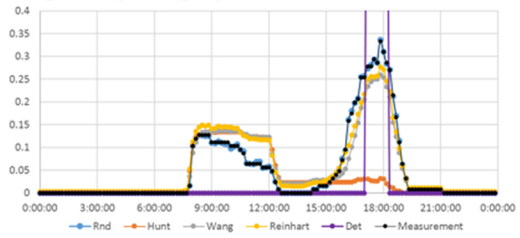
1. total duration of light on



2. lighting state matches



3. daily usage profile



• Recommendations for evaluation of building occupants' presence and behavior models: A blueprint (Mahdavi et al.)

The objective of this activity is to establish a framework for evaluating occupant models on their ability to reproduce observations. This addresses the problem that common methods for evaluating models have not been developed and that there are many different measures and outputs of models. Accordingly, a report that is being written will discuss how to compare and evaluate models with regards to predicting state, events and different spatial and temporal scales. To date, at least six scientific publications have arisen from this activity.

Subtask C:
Occupant action models in commercial buildings

Leader: Ardeshir Mahdavi, TU Wien, Austria
Liam O'Brien, Carleton University, Canada

- **Test of occupant action models (Wang et al.)**

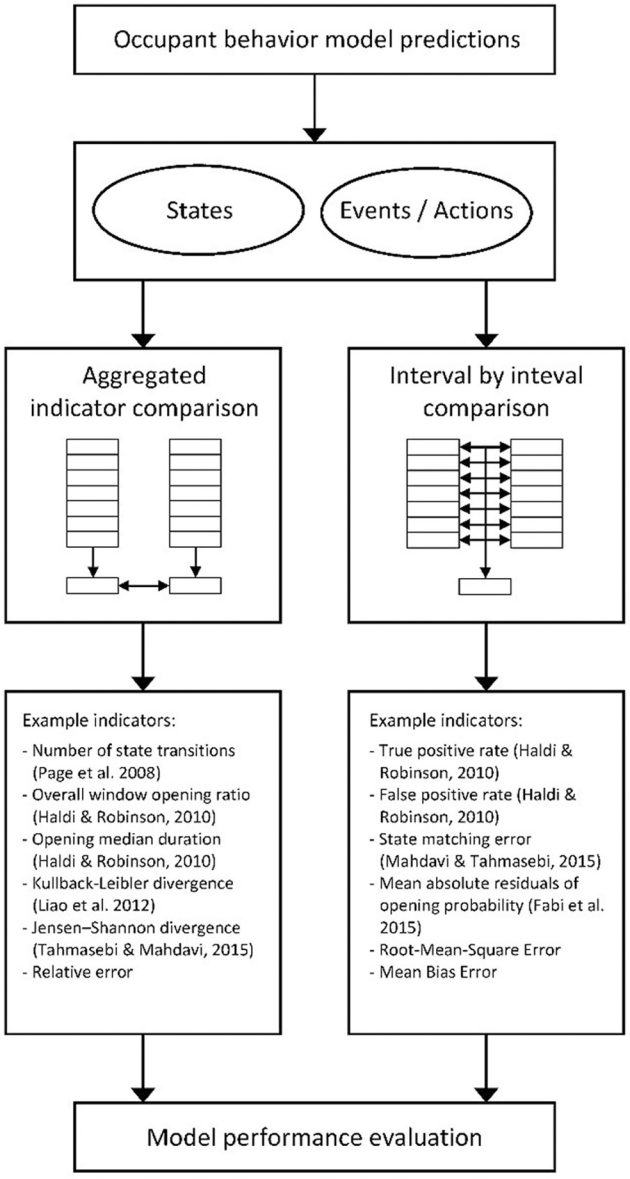
Activity 6.3 involves applying the methods developed in Activity 6.1 to existing and new models. Considerable progress - especially in respect to lighting - has been made on this initiative as shown in the figures below. Other action models to be explored include window opening, shading, and air-conditioning. This activity will result in several publications.

- **International survey on current occupant modelling approaches in building performance simulation (O'Brien et al.)**

This work related to an international survey on current occupant modelling practice and attitudes in building performance simulation. The survey included a 36-questions and was posted online using Google Forms to reach out approximately 5000 participants selected through the IBPSA members' emails.

In total, 274 valid responses were collected from building performance simulation users (practitioners, educators, and researchers) from 37 countries.

The results indicate that most assumptions made about occupants vary widely and are considerably simpler than what has been observed in reality. Most participants cited lack of time or understanding as their primary reason for not delving deeply into occupant modelling, but responded that they are receptive to further training



NEXT STEP

The main next steps are to continue publishing scientific papers and reports on the above topics. In most cases, the work is substantially complete. One of the objectives of Subtask C and Annex 66 is to disseminate findings to researchers and non-researchers. Thus, some of the results will be published in more available forms, including the final report of Annex 66.

Some of the participants of Subtask C are also heavily involved in other Annex 66 initiatives, including: writing a comprehensive book on studying occupants; conducting an international survey to understand better how practitioners are modeling occupants in BPS; and, implementing of occupant models into existing BPS tools and building design workflows. The Subtask C co-leaders are also co-editing a special issue of the Journal of Building Performance Simulation, along with Burak Gunay and Farhang Tahmasebi.

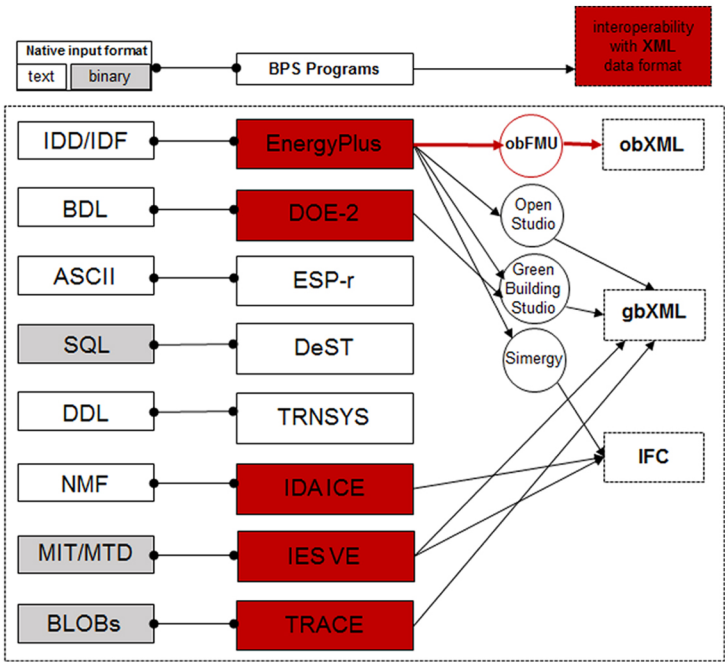
Subtask D:
Development and integration of occupant behavior modeling tools

Leader: Tianzhen Hong, LBNL, USA
Andrew Cowie, University of Strathclyde, UK

This subtask aims to better understand and fill in the gaps of modeling occupant behavior in building performance simulation, by developing new behavior modeling tools and integrating them with building performance simulation (BPS) programs. There are five main research activities: (1) Activity 7.1 – Survey and review of occupant behavior modeling with current BPS programs, (2) Activity 7.2 - Standard representation of occupant behavior models, (3) Activity 7.3 – Development of a software module with occupancy and occupant action models, (4) Activity 7.4 - Integration of occupancy and occupant action models with BPS programs, and (5) Activity 7.5 – A case study comparing occupant behavior modeling tools with various BPS programs.

ACHIEVEMENT

• **Activity 7.1**: We developed a questionnaire and surveyed subtask D participants on how EnergyPlus, DOE-2, DeST, ESP-r, TRNSYS, IDA-ICE, COMFIE and DesignBuilder handle occupant behavior input and/or models. Survey results (Figure 6) were collected and summarized in a report which was presented at the Ottawa meeting. Andrew Cowie of the University of Strathclyde is leading this activity.
• **Activity 7.2**: The obXML schema and a library of 52 occupant behavior models were released. Tianzhen Hong of LBNL is leading this activity.
• **Activity 7.3**: The obFMU, a co-simulation module with occupancy and occupant action models, was released. Tianzhen Hong of LBNL is leading this activity.
• **Activity 7.4**: We successfully implemented the co-simulation of obFMU with EnergyPlus and ESP-r. obFMU uses obXML for representation of occupant behavior models. Tianzhen Hong and Andrew Cowie are co-leading this activity.



• **Activity 7.5**: We are developing a case study to compare processes and results from using same occupant behavior models with EnergyPlus, ESP-r, and other approaches (e.g. using another occupant behavior FMU in Modelica). Sumee Park of Fraunhofer is leading this activity.
Three OB modeling tools, obXML, obFMU and the Occupancy Simulator, are released to the Annex 66 and IBPSA simulation communities.

NEXT STEP

• **Activity 7.1**: Write a conference paper for the IBPSA 2017 conference, and contribute to the final report as a summary of the main body and a part of an appendix.
• **Activity 7.2**: Enhance obXML to add new features and address users' feedback. Expand the library of occupant behavior models in obXML. Outreach to BIM community to discuss synergy between obXML and BIM (e.g., gbXML, CityGML).
• **Activity 7.3**: Enhance obFMU to add new features and address users' feedback.
• **Activity 7.4**: Release obFMU integration with ESP-r.
• **Activity 7.5**: Complete the case study and document the results in a report.
• Present the occupant behavior modeling tools to the ASHRAE community through the MTG.OBB.

Subtask E:
Applications in building design and operations

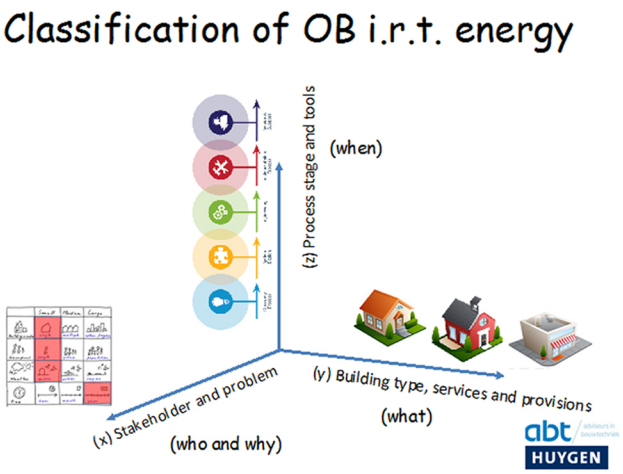
Leader: Khee Poh Lam, CMU, USA
Cary Chan, Hong Kong Green Building Council, Hong Kong
Clinton Andrews, Rutgers University, USA

Subtask E focuses on applications of occupant behavior modeling. It considers applications along the full life cycle of the building, including design, construction, commissioning, operation, and beyond. Key themes are the suitability of models for specific applications, the links between research and practice, and case studies and other ways of illustrating the value of models for these applications.

ACHIEVEMENT

Survey of current practices, needs, and demand for behavior and occupancy models in commercial buildings

This activity is now complete. Liam O'Brien has summarized the results in a paper that is available to Annex 66 participants and will be included as an appendix in the final report for the Annex.



Practical presentation of simulation results

This activity was redirected to become an exploration of effective ways to communicate the uncertainty associated with occupant behavior data and models. Liam O'Brien has now published a paper on this topic that is publicly available. It will be cited in the final report of the Annex.

Fit-for-purpose modeling review and guide

Pieter-Jan Hoes and Isabella Gaetani have now published a paper identifying the need for "fit-for-purpose" models, that is, models targeting specific applications. They are working on a follow-up paper aimed at satisfying this need and providing guidance to the range of models that exist.

Peter Op't Veld has been working on application categories to help guide this discussion. At the Ottawa meeting in August 2016, the Subtask E group discussed several alternative categorization strategies. The group recognized three reasons to pursue categorization: (1) identify "fit" for OB models; (2) classify case studies by contexts; and (3) classify users and applications for OB models.

Applications, represented by case studies, could be organized by location (country), building type (residential, commercial), building size, building life cycle stage, or other approach. They could be categorized with a more elaborate branching logic the subdivides applications into cohorts determined by answering who, why, what, and when questions. A simplification that reduces to three dimensions—when, what, and who and why—may be adequate for our purposes. More explicitly, the three dimensions are:

- Stakeholder and problem (who and why)
- Building type, services, and provisions (what)
- Process stage and tools (when)

During discussion of the categorization strategy, we noted that the "when" question raises an important challenge for the Annex 66 group. Stakeholders involved in early stages of the building life cycle, including program definition and system design, do not rely on simulation models. Instead they rely on benchmark data, rules of thumb, and design guides. Does Annex 66 want to contribute these items?

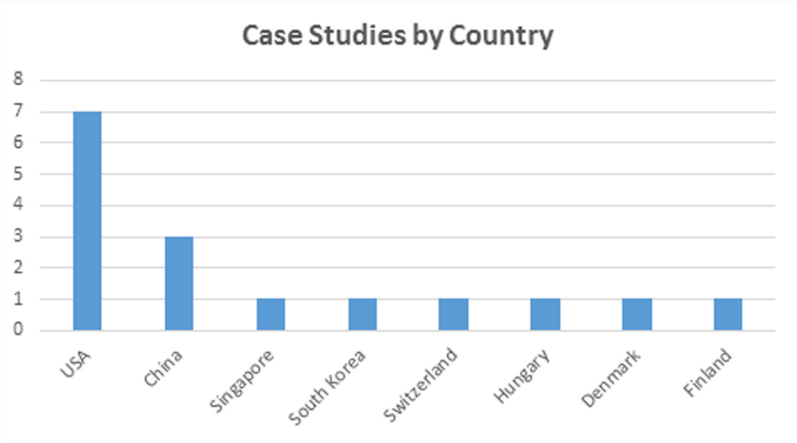
Subtask E:
Applications in building design and operations

Leader: Khee Poh Lam, CMU, USA
Cary Chan, Hong Kong Green Building Council, Hong Kong
Clinton Andrews, Rutgers University, USA

The engineering, construction, and operation stages of the building life cycle are more amenable to modeling, albeit ranging from simple decision tools and design tools through advanced design and operations tools. We suspect that we will not be able to fully satisfy practitioners desires for benchmarking and rule-of-thumb guidance as part of Annex 66, but we will note the gap.

Design Practitioners' Guide to Occupant Behavior in Office Buildings
Zsofia Belafi, Andras Reith, Julia Day, Holly Samuelson, and Astrid Roetzel volunteered to produce a design guide for occupant behavior in commercial buildings to answer the need identified above. To produce this guide in time to be included in the Annex, they need to tighten its scope, draw lessons from Annex conclusions about when OB matters, link to subtask C survey, create infographics, and target the trade press for distinct professional audiences. Since Ottawa, the group has produced an outline for the guide.

End-use services & OB
Joon-Ho Choi commented in Ottawa that the current Annex efforts have not focused on end-use services and that this is an important omission. He has volunteered to write a literature review on this topic. It will be included as an appendix in the final report.



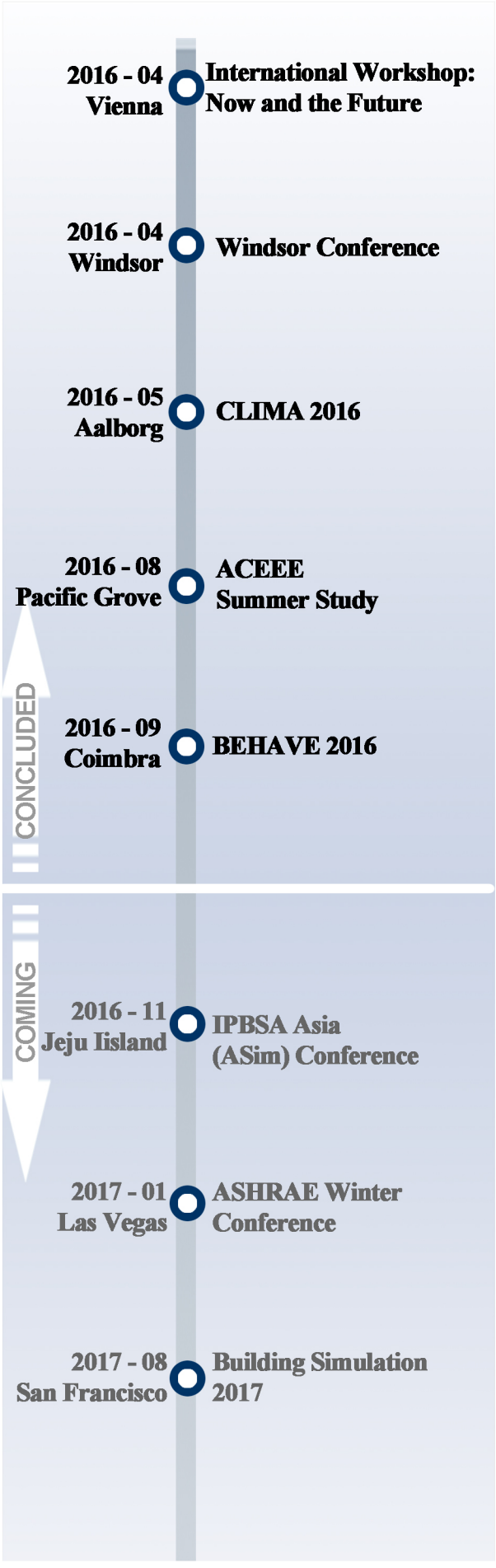
Special journal issue on applications of occupant behavior modeling
Clinton Andrews and Bing Dong are co-editing a topical (special) issue of Building Simulation on applications of occupant behavior modeling. They received 40 abstracts by early September and encouraged 32 authors to prepare full manuscripts, due at the end of November 2016. They will undergo peer review and revisions, and we expect to publish the topical issue on late 2017.

Case studies
Khee Poh Lam, Clinton Andrews, and others have prepared 16 case studies to date on applications of occupant behavior modeling. They seek additional cases, especially non-US cases. The additional cases should reflect the application categories previously mentioned and fill in gaps. Presentations on microsensing (Martha Hao) and metering advances (Cary Chan) shown at Annex meetings are becoming cases that fill in a gap on ways to influence occupant behavior. However, it would be good to recruit additional cases covering topics such as building construction and commissioning.

NEXT STEP

- Finalize classification scheme: key dimension is building life cycle stage, then look at other dimensions within each stage (Peter Op't Veld)
- Draft a chapter of the final report and a final appendix. Isabella Gaetani has circulated an outline of the chapter already.
- Recruit more case studies to fill gaps in classification scheme. Several volunteers at the Ottawa meeting promised to deliver non-US case studies.
- Write a modest effort at design guidance (Zsofia Belafi and colleagues) and end-use services (Joon-Ho Choi).

Workshop List



Concluded

• April 2016, Vienna

International Workshop on Implications of Occupant Behavior for Building Operation and Design: Now and the Future

The objective of this workshop was to identify the research gaps in existing occupancy behavior research, including obstacles, needs and future research directions for the academic and industry communities.

• April 2016, Windsor

The Windsor Conference 2016

This workshop focused on the understanding, modeling and simulation of occupant behavior in buildings. The IEA Annex 66 activities were introduced. Attendees discussed the progress of occupant behavior research in buildings. Topics of discussion included robustness of experiment design, advanced modeling development, methodologies of occupant behavior modeling, simulation, as well as model evaluation procedures.

• May 2016, Aalborg

CLIMA 2016

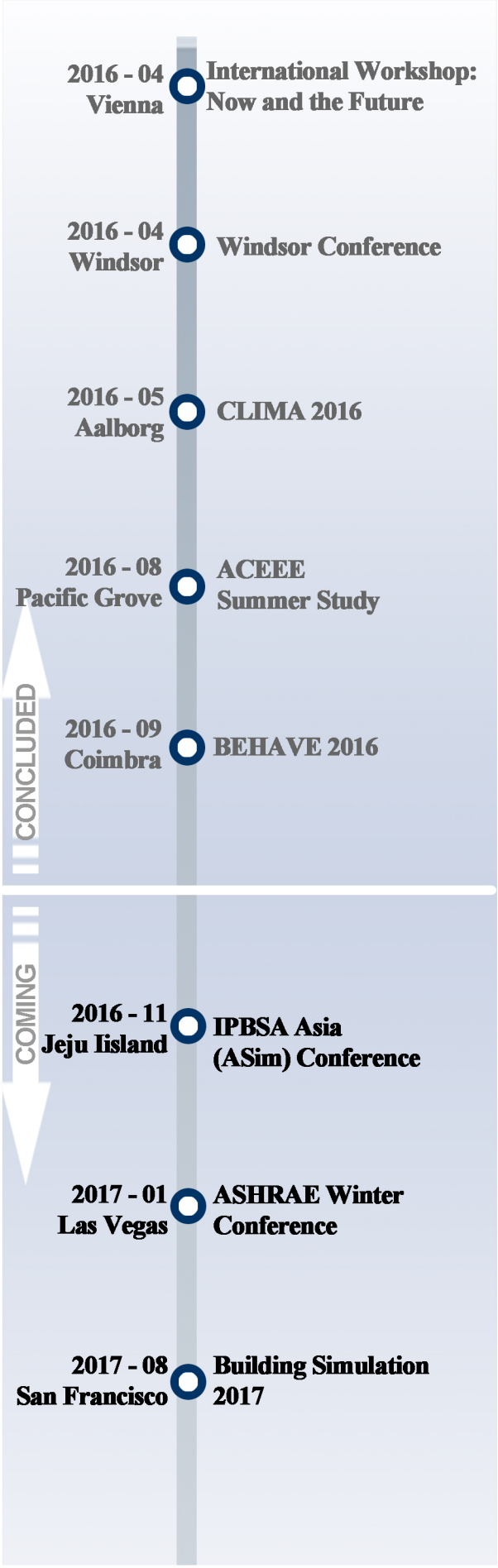
The 12th REHVA World Congress CLIMA 2016 focused on building and Heating, Ventilating and Air-Conditioning (HVAC) system performance. Specific concern arose during Workshop 19 "Building automation and control systems continuous operational energy use optimization" on the fulfilment of the intended design during operational phase, the control system ability to meet the needs of the occupants, as well as the users' interaction with the Building Automation Systems (BAS) in daily practice. In these contexts, the role of occupant's behavior in the smart energy system was discussed.

• August 2016, Pacific Grove

ACEEE Summer Study on Energy Efficiency in Buildings

During Panel 8 "Capturing Savings Through Behavior" participants discussed how to leverage occupant behavior to save energy and resource in buildings. Topics of discussion included: the behavioral component of clean energy solutions and programs targeting energy, water, waste and/or renewable energy at the scale of individual buildings and communities; the use of behavioral strategies to drive EE, demand reduction and installed measure programs; novel applications of behavioral science, as well as behavioral strategies proven to be cost-effective and scalable. Innovative and creative solutions to foster environmental behavior were also introduced, such as energy visualization, social media, smart building solutions, gamification, compelling product design, mobile applications, publicity campaigns, and the use of data analytics to model and understand impacts of behavior on energy use in buildings.

Workshop List



• **September 2016, University of Coimbra, Portugal.**
BEHAVE 2016 - 4th European Conference on Behaviour and Energy Efficiency
The IEA DSM Task 24 Workshop "Reframing the energy system" was held before the BEHAVE conference to provide an overview of the systemic issues related to behavioral change, as well as to provide hands-on solutions on how to solve such interdisciplinary topics collaboratively. Pre-conference meetings were followed by BEHAVE 2016, hosting around 240 participants from more than 30 countries. The main focus of the conference was to introduce and promote multidisciplinary research in the field of energy efficiency, with a particular regard to human behavior. Projects and concepts were hosted by the plenary speakers, Marco O'Malley and Linda Steg, to provide participants with insights into the engineering and psychological fields. A series of six parallel sessions gave a sneak peak to a broad range of research projects and case study applications. From the Annex 66 community, David Shipworth, Joana Abreu, Rune Andersen, Verena M. Barthelmes and Zsofia Belafi presented their ongoing research projects.

Coming

• **January 2017, Las Vegas, USA**
ASHRAE Winter Conference
A workshop will be held during the ASHRAE Winter Conferences to address the topic of occupant behavior, having title: 'An Introduction to ASHRAE Multidisciplinary Task Group on Occupant Behavior in Buildings". Chair of the Workshop will be Prof. Bing Dong, from University of Texas at San Antonio, San Antonio, TX. Four seminars will present highlights on state-of-art research on occupant behavior in building currently developed at LBNL (Tianzhen Hong), UTS (Bing Dong), Department of Energy (Marina Sofos), and Delos Living LLC (Jie Zhao).

• **August 2017, San Francisco, USA**
Building Simulation 2017
Building Simulation 2017 will bring together practitioners and researchers from around the world to share information about state of the art in simulation tools and applications and to discuss new developments. The conference will feature updates and insights regarding new research to improve simulation capabilities for advanced low-energy building systems, case studies from successful projects that demonstrate the key role that simulation plays, and ongoing efforts to enable compliance and building rating software to support radiant and other energy efficient systems.

Upcoming Experts Meetings



5th Annex 66 Experts Meeting and OB-17 Symposium

- **Location: Copenhagen, Denmark**
- **Dates: May 17-19, 2017**
- **Host University: Technical University of Denmark, Kgs. Lyngby, Denmark**

The 5th Experts Meeting in Working Phase will be hosted by Rune Andersen at DTU, the Technical University of Denmark, Copenhagen, Denmark from May 17th to 19th, 2017. OB-17 is the international symposium focusing on modeling of occupant behavior, thermal comfort, and adaptive opportunities. Presenters from broad backgrounds (engineering, architecture, psychology, sociology, marketing, etc.; researchers or practitioners) are encouraged to participate.

The aim of OB-17 is to stimulate discussions and debate about occupant behavior, thermal comfort, and adaptive actions. OB-17 will be linked to two IEA EBC Annexes (66 and 69). It will follow a two-day Annex 69 meeting (May 15 and 16) and will be followed by a two-day Annex 66 meeting (May 18 and 19). Both meetings and the OB-17 symposium will be hosted by DTU. DTU was founded in 1829 and is ranked as one of the foremost technical universities in Europe. The main campus is located in Kgs. Lyngby, 10-15 km from the center of Copenhagen. Please refer to www.annex66.org for details.

Upcoming Experts Meetings



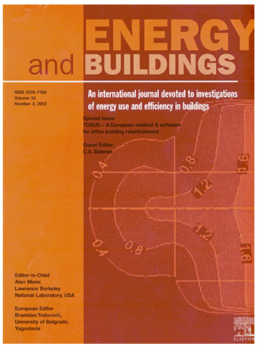
6th Annex 66 Experts Meeting

- **Location: Beijing, China**
- **Dates: September 25-27, 2017**
- **Host University: Tsinghua University, Beijing, China**

The last Annex 66 meeting will be hosted by Tsinghua University on September 25th to 27th, 2017 in Beijing. The meeting will be composed of an open symposium and a two-day expert meeting. Speakers will be invited to present their view on the topic from an industry, engineering research and social science research perspective. The achievements of activities, the final report, as well as a potential new annex will be discussed during the two-day expert meeting.

Tsinghua University is located in Haidian District, Beijing, the capital city of China. Beijing boasts a history of more than 3,000 years that has been proved by words and cultural relics. It is renowned for its opulent palaces, temples, parks, gardens, tombs, walls and gates, and its art treasures and universities have made it a center of culture and art in China. September is the best visiting time in Beijing regarding the climate. Please refer to www.annex66.org for details.

Special Issues



Five Special Issues have been organized:

- **Energy and Buildings**
  Advances in Building Energy Modeling and Simulation
  Guest editor: Tianzhen Hong

  Occupancy behavior in Buildings: modeling, simulation, and application
  Guest Editors: Andreas Wagner and Bing Dong

- **Building Performance Simulation**
  Guest Editors: Liam O'Brien, Ardeshir Mahdavi, Burak Gunay, Farhang Tahmasebi

- **Building Simulation**
  Applications of Occupant Behavior Modeling
  Guest Editors: Clinton Andrews, Bing Dong

- **Nature Scientific Data**
  Guest Editor: David Shipworth

National Participation

16 Official National Participants

Canada, China, Denmark, Italy, Korea, Poland, Spain
Netherland, New Zealand, Norway, UK, USA, Hungary, Australia
Austria, Germany

5 Soon-to-be Participants

France, Belgium, Portugal, Singapore, Turkey

4 Countries Showing Interest

Japan, Sweden, Switzerland, Brazil

Publications

Publications in 2016

[1] A. Mahdavi, M. Taheri, An ontology for building monitoring, Journal of Building Performance Simulation, 2016

[2] A. Mahdavi, F. Tahmasebi, On the quality evaluation of behavioural models for building performance applications, Journal of Building Performance Simulation, 2016

[3] A. Mahdavi, F. Tahmasebi, M. Kayalar, Prediction of plug loads in office buildings: Simplified and probabilistic methods, Energy and Buildings, 2016

[4] F. Tahmasebi, A. Mahdavi, An inquiry into the reliability of window operation models in building performance simulation, Building and Environment, 2016

[5] F. Tahmasebi, A. Mahdavi, The sensitivity of building performance simulation results to the choice of occupants' presence models: a case study, Journal of Building Performance Simulation, 2016

[6] A. Mahdavi, F. Tahmasebi, The deployment-dependence of occupancy-related models in building performance simulation, Energy and Buildings, 2016

[7] X. Liang, T. Hong, Q. Shen. Improving the accuracy of baseline energy models for commercial buildings with occupancy data. Applied Energy, 2016.

[8] X. Liang, T. Hong, Q. Shen. Occupancy data analytics and prediction: a case study. Building and Environment, 2016.

[9] T. Hong, S. C. Taylor-Lange, S. D'Oca, D. Yan, S. Corgnati. Advances in Research and Applications of Energy-Related Occupant Behavior in Buildings. Energy and Buildings, 2016.

[10] T. Hong, H. Sun, Y. Chen, S. Taylor-Lange, D. Yan. An Occupant Behavior Modeling Tool for Co-Simulation. Energy and Buildings, 2016.

[11] H. Kazmi, S. D'Oca, C. Delmastro, S. Lodeweyckx, S.P. Corgnati. Generalizable occupant-driven optimization model for domestic hot water production in nZEB. Applied Energy, 2016

[12] C. Wang, D. Yan, H. Sun, Y. Jiang. A generalized probabilistic formula relating occupant behavior to environmental conditions. Building and Environment, 2016

[13] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison and J. Bursill. Implementation of an adaptive occupancy and building learning temperature setback algorithm. ASHRAE Transactions, 2016

[14] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison, P. Bisaillon, and Z. Shi. Development and implementation of control-oriented models for terminal heating and cooling units. Energy and Buildings, 2016

[15] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison, and S. Gilani. Modeling plug-in equipment load patterns in private office spaces. Energy and Buildings, 2016

[16] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison. Control-oriented inverse modeling of the thermal characteristics in an office. Science and Technology for the Built Environment, 2016

[17] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison, and S. Gilani. Development and implementation of an adaptive lighting and blinds control algorithm. Building and Environment, 2016

[18] S. Gilani, W. O'Brien, HB. Gunay, JS. Carrizo. Use of dynamic occupant behavior models in the building design and code compliance processes, Energy and Buildings, 2016

Publications

[19] F. Tahmasebi, M. Schuss, A. Mahdavi, Exploring the effectiveness of window operation models for thermal comfort and energy performance assessments, Proceedings of the CESBP Central European Symposium on Building Physics & BauSIM, 2016

[20] A. Mahdavi, M. Del Bolgia, F. Tahmasebi, M. Schuss, Prediction of user-driven window operation in buildings, Proceedings of the 14TH International Conference of Indoor Air Quality and Climate, Ghent, Belgium, 2016.

[21] A. Mahdavi, M. Del Bolgia, F. Tahmasebi, Understanding the user-driven natural ventilation in Buildings: Can we benefit from the operationalisation of high-level human-ecological concepts?, Proceedings of 9th Windsor Conference, 2016.

[22] S. D'Oca, S.P. Corgnati, A.L Pisello, T. Hong. Introduction to an occupant behavior motivation survey framework, Proceeding of Clima2016 Conference, 2016

[23] Z. Belafi, T. Hong, A. Reith. A library of building occupant behavior models represented in a standardized schema, presented at BEHAVE 2016.

[24] Y. Chen, X. Luo, T. Hong. An Agent-Based Occupancy Simulator for Building Performance Simulation. presented at ASHRAE Annual Conference, 2016

[25] W. O'Brien and H.B. Gunay. Occupant behaviour diversity modelling and its applications. Presented at the eSim, Hamilton, Canada, 2016.

[26] H.B. Gunay, W. O'Brien, and I. Beausoleil-Morrison. A toolkit for developing data-driven occupant behaviour and presence models. Presented at the eSim, Hamilton, Canada, 2016.

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[28] A. Mirakhorli, B. Dong. Occupancy behavior based model predictive control for building indoor climate - A critical review. Energy and Buildings, 2016, Accepted

[29] W. O'Brien, S. Gilani, I. Gaetani, S. Carlucci, P. Hoes, JLM. Hensen. International survey on current occupant modelling approaches in building performance simulation, Journal of Building Performance Simulation, 2016, Accepted

[30] S. Corgnati, V. Fabi, S. D'Oca et al. REHVA Guidebook. Chapter 9. Behavior change – occupants' interaction with building automation and controls, 2016, Accepted

[31] S. Corgnati, F. Cotana, S. D'Oca et al. Cost-Effective Energy Efficient Building Retrofitting: Materials, Technologies, Optimization and Case Studies. Chapter 14 – A cost-effective human based energy retrofitting approach, 2016 Accepted

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[1] A. Mahdavi, Human Ecology and Building Science: A Necessary Synthesis, Sustainable Human–Building Ecosystems, 2015

[2] A. Mahdavi, F. Tahmasebi, Predicting people's presence in buildings: An empirically based model performance analysis, Energy and Buildings, 2015

[3] A. Roetzel. Occupant behaviour simulation for cellular offices in early design stages - Architectural and modelling considerations, Building Simulation, 2015

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[4] D. Yan, W. O'Brien, T. Hong, X. Feng, H. B. Gunay, F. Tahmasebi, A. Mahdavi. Occupant behavior modeling for building performance simulation: current state and future challenges, Energy and Buildings, 2015

[5] E. Azar and C. Menassa. Evaluating the impact of extreme energy use behavior on occupancy interventions in commercial buildings, Energy and Buildings, 2015

[6] E. Azar and C. Menassa. Optimizing the performance of energy-intensive commercial buildings: An occupancy-focused data collection and analysis approach. Journal of Computing in Civil Engineering, American Society of Civil Engineers (ASCE), 2015

[7] W. O'Brien and H.B. Gunay. Mitigating office performance uncertainty of occupant use of window blinds and lighting using robust design, Building Simulation, 2015

[8] H.B. Gunay, W. O'Brien, W. and I. Beausoleil-Morrison. Development of an occupancy learning algorithm for terminal heating and cooling units, Building and Environment, 2015

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[10] B. Huchuk, H.B. Gunay, W. O'Brien, and C.A. Cruickshank. Model-based predictive control of office window shades, Building Research & Information, 2015

[11] T. Hong, Y. Chen, S.C. Taylor-Lange, H. Sun, D. Yan. An occupant behavior modeling tool for co-simulation, Energy and Buildings, 2015

[12] T. Hong, S. D'Oca, S.C. Taylor-Lange, W. J.N. Turner, Y. Chen, S. P. Corgnati. An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAs Framework using an XML schema, Building and Environment, 2015

[13] T. Hong, S.C. Taylor-Lange, S. D'Oca, D. Yan, S. Corgnati. Advances in Research and Applications of Energy-Related Occupant Behavior in Buildings, Energy and Buildings, Engineering Advances, 2015

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[15] S. D'Oca and T. Hong. Occupancy schedules learning process through a data mining framework, Energy and Buildings, 2015

[16] X. Ren, D. Yan, T. Hong. Data Mining of Space Heating System Performance in Affordable Housing, Building and Environment, 2015

[17] X. Ren, D. Yan, T. Hong. Simulation of occupancy in buildings, Energy and Buildings, 2015

[18] T. Cholewa and A. Siuta-Olcha. Long term experimental evaluation of the influence of heat cost allocators on energy consumption in a multifamily building, Energy and Buildings, 2015

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