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

Energy related occupant behavior in buildings is a key issue for building design optimization, energy diagnosis, performance evaluation, and building energy simulation due to its significant impact on real energy use and indoor environmental quality in buildings. However, the influence of occupant behavior is under-recognized or over-simplified in the design, construction, operation, and retrofit of buildings. Occupant behavior is complex, stochastic and multi-disciplinary. Having deep understanding of occupant behavior and being able to model and quantify its impact on use of building technologies and energy performance of buildings is crucial to the design and operation of low energy buildings. Existing studies on occupant behavior, mainly from the perspective of sociology, lack in-depth quantitative analysis. There are over 20 groups all over the world studying occupant behavior individually. The occupant behavior models developed by different researchers are often inconsistent, with a lack of consensus in common language, in good experimental design and in modeling methodologies. Due to the complexity and the great regional difference of occupant behavior, it is a prerequisite for researchers to work together to define and simulate occupant behavior in a consistent and standard way. The Annex aims to set up a standard occupant behavior definition platform, establish a quantitative simulation methodology to model occupant behavior in buildings, and understand the influence of occupant behavior on building energy use and the indoor environment. We hope to provide scientific description and clear understanding of energy-related occupant behavior in buildings, as well as research methodologies and simulation tools to bridge the gap between occupant behavior and the built environment, thus to assist building design, operation, and energy technologies evaluation through the close co-operation of researchers all over the world.

2nd Expert Meeting in Working Phase
August 3rd – 5th, Karlsruhe Institute of Technology, Germany

FORUMS & EXPERT MEETINGS

FINISHED

- **2013 - 08 Paris** — **Expert Meeting for New ANNEX**
- **2014 - 03 Hong Kong** — **Expert Meeting Preparation Phase -1**
- **2014 - 08 Nottingham** — **Expert Meeting Preparation Phase -2**
- **2015 - 04 Berkeley** — **1st Expert Meeting of Working Phase**
- **2015 - 08 Karlsruhe** — **2nd Expert Meeting of Working Phase**

COMING

- **2016 - 03 Vienna** — **3rd Expert Meeting of Working Phase**
- **2016 - 08 Ottawa** — **4th Expert Meeting of Working Phase**
- **2017 - 04 Copenhagen** — **5th Expert Meeting of Working Phase**
- **2017 - 08 Beijing** — **6th Expert Meeting of Working Phase**

In the year 2015, a dozen research activities aiming to achieve the project objectives are making great progress. The occupant behavior literature database, with 484 papers, was developed and made available at Annex66.org. The special issue of Energy and Buildings which has seven articles on advances in occupant behavior modelling and simulations was also completed in this year. Eight occupant behavior workshops and seminars were organized at various conferences, while more than 50 journal articles and conference papers were published. Furthermore, there is a new Multidisciplinary Task Group of ASHRAE, MTG.OBB being formed in this period. This Task Group will focus on the integration of occupant behavior into ASHRAE standards, guidelines, and research projects.

Outcomes from those open forums have greatly supported our research work of Annex 66. Reports and presentations from the industry field focused on real projects and pointed out the application of this research; sociologists and psychologists strengthened our theoretical principle with their research findings; communications with ASHRAE also helped us to integrate outcomes of Annex 66 into existing standards. Until now, we already have a clear guideline and done some case studies. The new simulation tool with detail consideration of occupant behavior is underway. It will make building simulation results more close to the reality.

2nd Expert Meeting in Working Phase, Karlsruhe

The second Expert Meeting was successfully concluded in KIT, Karlsruhe, Germany. The three-day meeting took place August 3rd to 5th, 2015. Sixty participants from 14 countries attended the two-day Annex 66 meetings. Many activities made significant progress. Three cross-task research topics, behavioral data collection and database, social and behavioral influencing factors, and behavior model evaluation and application, were discussed among all participants. Two special journal issues of Energy and Buildings are being managed by Tianzhen Hong, Andreas Wagner, and Bing Dong, with 34 articles submitted on the research area of occupant behavior in buildings. Participants visited KIT's facility LOBSTER, Laboratory for Occupant Behavior, Satisfaction, Thermal Comfort and Environmental Research.

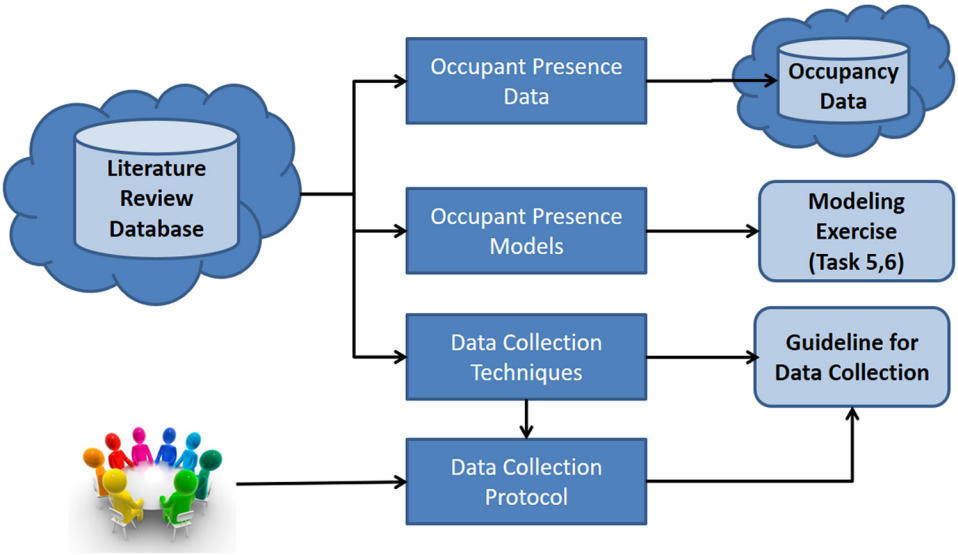
Subtask A:
Occupant movement and presence models in buildings

Leader: Andreas Wagner, Germany
Co-Leader: Bing Dong, USA

INTRODUCTION

This subtask aims at providing a description and simulation methodology for different personnel presence and movement. One further objective is to provide information on data collection with regard to movement and presence in buildings. As a cross-sectional activity, the participants in Subtask A will construct an occupancy monitoring guideline within the whole context of occupant behavior.

Scope of Subtask A is as follow: Literature review on the state of the art, also taking into account work in other domains dealing with simulation of occupant presence and movement; escription of sensor technology and data collection methods providing useful data for modeling occupant presence and movement; collection of monitoring data for a general Annex 66 database; description of modeling techniques, models and model validation for occupant presence and movement; collection and provision of models for a general Annex 66 repository.



There are four Activities/Deliverables of Subtask A:
- Build up a matrix in order to structure important questions about occupant presence and movement and to clarify the hierarchy of topics;
- Conduct a literature review on modeling techniques of occupant presence and movement;
- Investigate the possibility of creating a head-to-head comparison framework for occupant behavior models;
- Structure the occupancy monitoring guideline for occupant presence and movement.

ACHIEVEMENT

- The literature review database has been finished and now it is published on the Annex website.
- In the process of finalizing a special journal issue to be published in the International Journal of Energy and Buildings.
- In addition, the occupancy monitoring guideline consists of 10 chapters, and we have more than 20 authors.

NEXT STEP

- Finalize occupancy monitoring guideline and improve it.
- Publish papers on review of modeling techniques of occupant presence and movement.
- Finalize a special journal issue that will be published in the International Journal of Energy and Buildings.

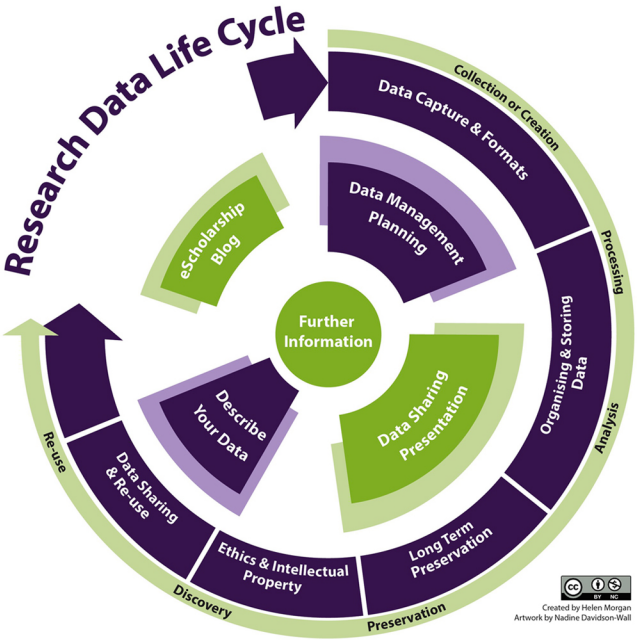
Subtask B:
Occupant action models in residential buildings

Leader: Darren Robinson, UK
Co-Leader: Henrik Madsen, Denmark

INTRODUCTION

This subtask will address 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 will be addressed. This subtask will coordinate efforts to lessen the severity of the above inconsistencies, with the spirit that models are supposed to be integrated into a coherent whole. Avoiding replication and channeling efforts where most needed will be essential.

Scope of Subtask B is as follows: 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

- Data was collected and prepared for the database.
- Until the end of October, the structure of the database was defined and the first dataset was uploaded.
- In June 2015, a summer school "Modeling the thermal characteristics of buildings" was successfully held by Technical University of Denmark (DTU). In this summer school, a model was founded using Grey-box modelling approach (CTSM-R and a RC-model). The thermal dynamics of a building integrated and ventilated PV module was also modelled and discussed during this summer school.

NEXT STEP

- General database for occupancy data
- Guideline to different modeling approaches for occupant behavior in residential buildings
- Investigation of thermal comfort, psychology and sociology in occupant behavior research
- Methods of modelling occupants' operation on other devices
- Grey-box modelling

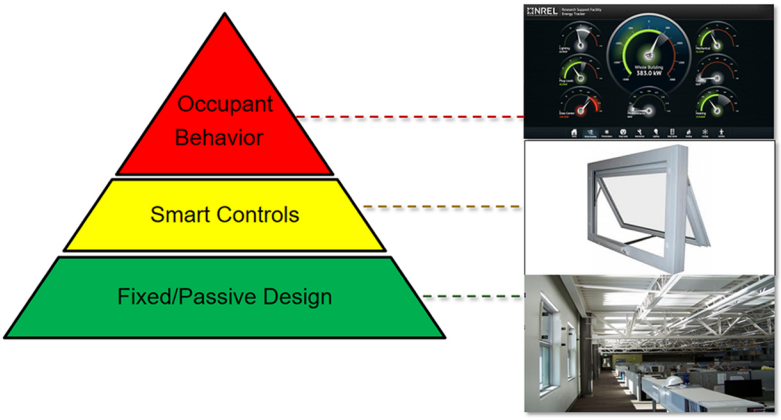
Subtask C:
Occupant action models in commercial buildings

Leader: Ardeshir Mahdavi, Austria
Co-Leader: Liam O'Brien, Canada

INTRODUCTION

Modelling occupants' behavior in commercial buildings involve some specific challenges given the complexity and diversity of the respective processes. A commercial building is typically operated via complex environmental control systems, and the control degrees of freedom between occupants and building or system managers can substantially vary from building to building. Moreover, occupants in commercial buildings often work in shared spatial settings and interact within a social field that requires collaboration and negotiation.

Scope of Subtask C includes: Empirical observations of occupant behavior and collection of data via monitoring equipment; Development of mathematical/statistical modelling methods and tools; Evaluation of the occupant behavior models by comparison with empirical observations; Applications in real cases as guidelines for field survey and simulation.



There are 4 Activities and Deliverables: review of different modeling approaches for occupant behavior in buildings; approach to address occupants' behavior diversity in model development; recommendations for evaluation of building occupant presence and behavior models; documentation of best practices in occupancy model testing and evaluation

ACHIEVEMENT

- Given the variety of occupancy-related models for building performance simulation, in Subtask C we conducted a comprehensive review of different approaches to model occupant presence and behavior with a focus on commercial buildings.
- In addition, as the diversity among occupants is infrequently recognized in occupancy-related models, the existing methods to represent occupant diversity have been examined using a rich repository of observational data on occupant presence and use of equipment.
- This ongoing study provides a basis toward a more rigorous representation of occupants in building performance simulation models.
- Subtask C also addressed the potentially detrimental uncertainties in use of occupancy-related models by conducting systematic evaluation of a number of occupant presence and behavior models.

NEXT STEP

- The review of occupancy-related models for commercial buildings is to be finalized.
- Joint efforts in Subtask C continue the study on modeling occupancy diversity, using different set of occupancy-related observational data obtained from commercial buildings in different settings.
- The evaluation efforts pertaining to occupants' presence and behavior models shall be continued toward the development of a blueprint for the quality assessment of occupancy-related models.
- This study also provides the basis for formulation of the relationship between the proper choice of occupancy-related models and the pertinent purpose of the simulation-based query.

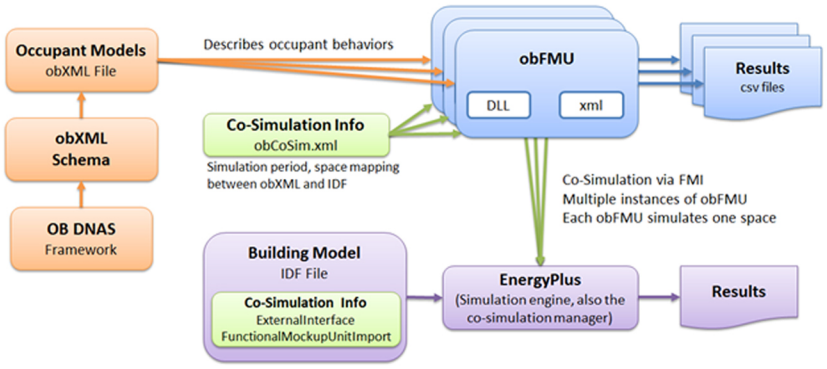
Subtask D: Development and integration of occupant behavior modeling tools with building simulation programs

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

INTRODUCTION

This subtask aims to better understand and fill in the gaps of modeling occupant behavior in building simulation by developing new occupant behavior modeling tools and integrating them with building simulation programs.

There are 5 main research activities:
Activity 7.1: Occupant behavior modeling with current building simulation programs; Activity 7.2: Standard representation of occupant behavior models; Activity 7.3: Development of a software module with occupancy and occupant action models; Activity 7.4: Integration of occupancy and occupant action models with building simulation programs; Activity 7.5: Case studies evaluating the developed occupant behavior modeling tools.



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 were collected and summarized in a report which will be presented at the Vienna meeting.
- Activity 7.2: We developed a DNAS framework and an XML schema obXML to standardize representation of occupant behavior models for integration with building simulation programs. obXML was released for review and testing. We are developing a library of occupant behavior models in obXML.
- Activity 7.3: We developed obFMU, a co-simulation module with occupancy and occupant action models. obFMU was released for review and testing.
- Activity 7.4: We successfully implemented the co-simulation of obFMU with EnergyPlus. obFMU uses obXML for description of occupant behavior models.
- Activity 7.5: We developed case studies using obXML and obFMU with EnergyPlus, and compared results against other approaches (e.g, using another occupant behavior FMU in Modelica).
- A public webinar on March 15, 2016 was conducted to introduce the occupant behavior modeling tools. About 100 participants from academia, research and industry around the world attended the webinar. Valuable feedback was received to help improve the tools for practical applications.

NEXT STEP

- Activity 7.1: Refine the report and potentially write a conference paper.
- Activity 7.2: Enhance obXML to add new features and address reviewers' comments. Complete the library of occupant behavior models in obXML. Outreach to BIM community to discuss synergy between obXML and gbXML.
- Activity 7.3: Enhance obFMU to add new features and address reviewers' comments. Outreach to more energy modelers and software developers to adopt obFMU.
- Activity 7.4: Address limitations of EnergyPlus FMI to fully integrate obFMU. Continue effort to integrate obFMU with ESP-r.
- Activity 7.5: Complete the case studies using updated obXML and obFMU. Document the case studies in a report.

Subtask E:
Applications in building design and operations

Leader: Khee Poh Lam, USA
Co-Leader: Cary Chan, Hong Kong, China

INTRODUCTION

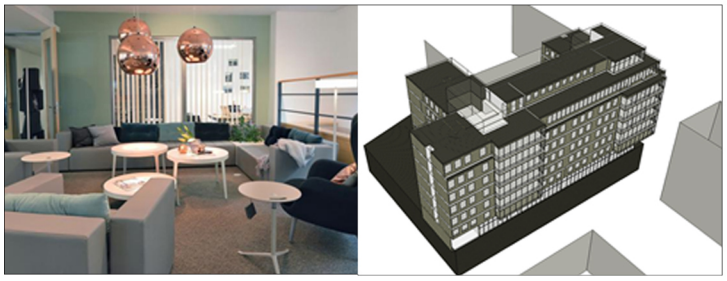
Subtask E aims to deploy and demonstrate the use of methods and tools developed in Annex 66, to improve building design, operations, and energy performance by case studies. The expected output is to establish a set of behavioral guidelines exemplified with case studies to illustrate the impact of occupant behavior on building design and operations. Scope of Subtask E is as follows: Understand the needs in the industry and current research in academia; standardize the model input/output requirements and occupant model performance evaluation; use case studies to apply the models and software tools in real buildings and to validate software applications; Provide feedback on software user-friendliness and effectiveness; Develop guidelines for simulating occupant behavior in buildings; Promote the outcomes in industry.

Activities and Deliverables of Subtask E:
A literature review on the input/output of various types of occupant behavior was conducted. An industry survey based on the literature review and industry experience was completed in the end of 2014. As a cross-sectional activity, Subtask E will work with Subtask A, B, and C to standardize various occupant behavior model input/output requirements. General Deliverables include: Case studies to apply the models and software tools in real buildings; and occupant behavior guidelines for design, construction and operations.

ACHIEVEMENT

- Smart building management versus intuitive human control for office buildings, Budapest, Hungary
- Global lighting performance:Annual survey of blinds movements of three office buildings in Lausanne, Switzerland
- 10 houses in Erhezhuang Village, Beijing, China
- Whole building study - Center for Sustainable Landscapes, Pittsburgh, PA
- Improving Occupancy Presence Prediction Via Multi-Label Classification
- Case study from Philadelphia

Smart Building Management vs. Intuitive Human Control



NEXT STEP

- Update on latest CLP Meter Online System V. 3.0, launched Nov 2015
- Report on practical implementation of electricity consumption data collection and accuracy analysis in experimental test beds as well as ongoing development of data mining techniques to discover occupant behavior
- Proposal to install Defond system in some of the above case studies for comparative study
- Generic occupants data set for design guidance
- Thoughts on how to serve both research-level modelers and creators of standard practice-oriented models when developing co-simulation tools such as obXML-EnergyPlus
- Integrating social-psychological, customer segmentation and demographic factors into residential demand response programs
- Public goods dilemmas: dilemmas of achieving thermal comfort, and energy saving behaviors and communication to save energy in commercial buildings
- Masters thesis project on “Verification, validation and enhancement of an agent-based occupancy simulation model for building performance simulation”. Carnegie Mellon University
- Implement models provided by Sub-Task D on selected case studies

Activity List:

No.	Activity	Proposed Leader(s)	Subtask Lead
1	**Introduction to Annex 66**		
2	**Definition and framework**		
3	**State-of-the-art**		
	3.1. Occupant behavior related literature database	Bing Dong, Tianzhen Hong	A
	3.2. Investigation of occupant presence data and models	Bing Dong, Chuang Wang	A
4	**Data collection**		
	4.1. Current data collection techniques	Bing Dong, Andreas Wagner	A
	4.2. Occupancy and occupant behavior data collection protocol	Liam O'Brien, Andreas Wagner, Bing Dong, Darren Robinson	A
	4.3. General database for monitoring data	David Shipworth	B
	4.4. Reference procedures for obtaining occupancy profiles in residential buildings	Marilena De Simone	B
5	**Modelling**		
	5.1. Guideline to different modeling approaches for occupant behavior in residential buildings	Henrik Madsen	B
	5.2. Guideline to different modeling approaches for occupant behavior in commercial buildings	Burak Gunay, Liam O'Brien	C
	5.4. Approaches to address occupants' behavior diversity in model development	Liam O'Brien, Ardeshir Mahdavi, Farhang Tahmasebi, Burak Gunay	C
	5.5. Methodologies of modelling occupant presence	Bing Dong	A
	5.10. Methodologies of modelling occupants' operation on other devices	Yohei Yamaguchi	B
	5.11 Integration of social psychological and group dynamic analysis of occupant behavior in buildings	Chien-fei Chen	B
6	**Evaluation of models**		
	6.1. Recommendations for evaluation of building occupants' presence and behavior models: a blueprint	Ardeshir Mahdavi, Farhang Tahmasebi	C
	6.3. Test of occupant action models	Chuang Wang	C
7	**Integration with BPS tools**		
	7.1. Background on occupant behavior simulation with BPS	Andrew Cowie	D
	7.2. Standard description and protocols of occupant behavior in simulation	Simona D'Oca	D
	7.3. Occupancy and action software module development	Tianzhen Hong, Da Yan, Yixing Chen, Hongsan Sun	D
	7.4. Integration of occupancy and action models in BPS tools	Tianzhen Hong, Da Yan	D
	7.5. Case studies using the occupant behavior tools with BPS program	Sumee Park	
8	**Applications**		
	8.1. Investigation of current demand for occupant behavior simulation in buildings	Khee Poh Lam	E
	8.2. Documentation of current practices for models in residential buildings	Yiwen Jian	
	8.3. Documentation of current practices for models in commercial buildings	Liam O'Brien, Sara Gilani	E
	8.4. Levels and adaptability of modelling in applications	Jan Hensen, Pieter-Jan Hoes	E

Activity List:

No.	Activity	Proposed Leader(s)	Subtask Lead
	8.5. Guideline to practical presentation and deployment of conventional and probabilistic simulation results	Sara Gilani, Liam O'Brien, Ardeshir Mahdavi, Farhang Tahmasebi	E
	8.6. Case studies in engineering and industry (Several groups)	Khee Poh Lam, Cary Chan	E
	8.7. Micro-Sensing Research & Development Project	Martha Hao	E
	8.8. Hostel Environmental Training	Cary Chan	E
	8.9. Green Building Initiatives and New Meter Online Service	Simon Lam	E
9	**Publicity**		
	9.1. Annex 66 newsletter and EBC articles	Tianzhen Hong, Da Yan, Liam O' Brien, Panyu Zhu, Xiaohang Feng	Management
	9.2. Website management	Sang Hoon Lee	Management
	9.3. Annex 66 meetings (ExCo Meetings, Expert Meetings, Calls)	Tianzhen Hong, Da Yan, and subtask leads	Management
	9.4. Topical journal issues	Liam O'Brien, Andreas Wagner, Tianzhen Hong, Da Yan	Management
10	**Outreach**		
	10.1. Meeting information management	Sebastian Wolf, Quentin Darakdjian	Management
	10.2. Outreach - ASHRAE handbook and seminars	Tianzhen Hong, Da Yan, Bing Dong, Clinton Andrews	Management
	10.3. Outreach - IBPSA conferences	Liam O'Brien, Tianzhen Hong	Management
	10.4. Outreach – CIBSE	David Shipworth	Management
	10.5. Outreach – REHVA	Stefano Cognati	Management

UP COMING MEETINGS

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

3rd Expert Meeting in the working phase

Vienna, Austria
March 30 - April 1, 2016
Host: Prof. Ardeshir Mahdavi,
Vienna University of Technology

Carleton UNIVERSITY

4th Expert Meeting in the working phase

Ottawa, Canada
August 3 - 5, 2016
Host: Prof. Liam O'Brien,
Carleton University

WORKSHOP

FINISHED

- 2015 - 06 Torino — **IBPC Workshop**
- 2015 - 07 Tianjin — **ISHVAC-COBEE**
- 2015 - 10 Pittsburgh — **FISSHBE Workshop**
- 2015 - 10 Dalian — **Cold Cilmate HVAC**
- 2016 - 01 Orlando — **ASHRAE 2016 Winter Conference**

COMING

- 2016 - 04 Vienna — **US NSF International Workshop**
- 2016 - 04 Windsor — **Windsor Conference**
- 2016 - 05 Aalborg — **CLIMA 2016**
- 2016 - 08 Pacific Grove — **ACEEE Summer Study**

Workshops on occupant behavior research have been held in various international conferences. Typically five academic presentations by experts were included in each workshop. These workshops aim to have a deep discussion about progress and challenges, as well as future perspectives in occupant behavior research. The focus is on measurement, modeling methods and simulation results of impacts of occupant behavior on energy performance of buildings. The research findings can improve and expand the use of simulations to support the design and operation of low energy buildings considering the occupant dimension. The communication among researcher has inspired new ideas on occupant behavior research. Attendees have discussed the progress of occupant behavior research in buildings, the experience of addressing problems they have encountered during modelling, and discuss how to achieve rigorous modelling with a well-developed scientific framework, which aims to reach a common agreement on methodologies of occupant behavior modelling and simulation.

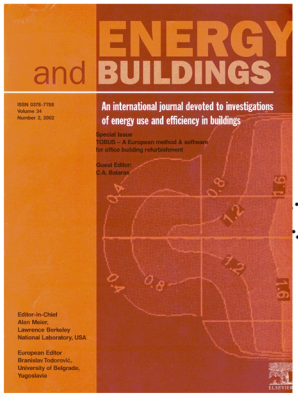
The objective of the US NSF International Workshop is to identify the research gaps in existing occupancy behavior research including what the obstacles are and what is needed from both NSF and industry, and the identification of future research directions.

The 9th Windsor Conference provides an opportunity for leading thermal comfort experts to share latest developments and explore synergies particularly this year on the pressing subject of how to use comfort expertise to design buildings and comfort systems that are genuinely low energy, comfortable and sustainable.

CLIMA 2016 will especially focus on energy efficient building and HVAC system performance in practice both in relation to fulfilment of the intended design, in relation to their ability to fulfill the needs of the occupants and interact with the users daily practice as well as in relation to their role in the future smart energy system.

ACEEE Summer Study is planned to be the pre-eminent meeting to discuss the technological basis for, and practical implementation of, actions to reduce energy use and the climate impacts associated with buildings.

SPECIAL ISSUES



Advances in BEM and Sim

- Journal: Energy and Buildings
- Guest editor: Tianzhen Hong
- 15 invited articles
- Published in March 2016.

Occupancy Behavior in Buildings: Modeling, Simulation and Applications

- Journal: Energy and Buildings
- Guest editors: Andreas Wagner and Bing Dong
- 75 abstracts received, 30 has been approved to submit full paper
- To be published in March, 2016

Journal of Building Performance Simulation

- Guest editor: Liam O'Brien; Ardeshir Mahdavi; Burak Gunay; Farhang Tahmasebi
- To be published in 2016

NATIONAL PARTICIPANTION

13 Official National Participants

Canada, China, Denmark, Italy, Korea, Poland, Spain

Netherland, New Zealand, Norway, UK, USA, Hungary

7 Soon-to-be Participants

Austria, France, Belgium, Portugal

Germany, Japan, Turkey

5 Countries Showing Interest

Australia, Singapore, Sweden, Switzerland, Brazil

PUBLICATION

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PUBLICATION

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