International Energy Agency

EBC
Energy in Buildings and Communities Programme

Energy Efficiency and Behavior Workshop

Annex 66
Definition and Simulation of Occupant Behavior in Buildings

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Mar 12, 2015

Background

- **Large gaps between field data and simulation result**

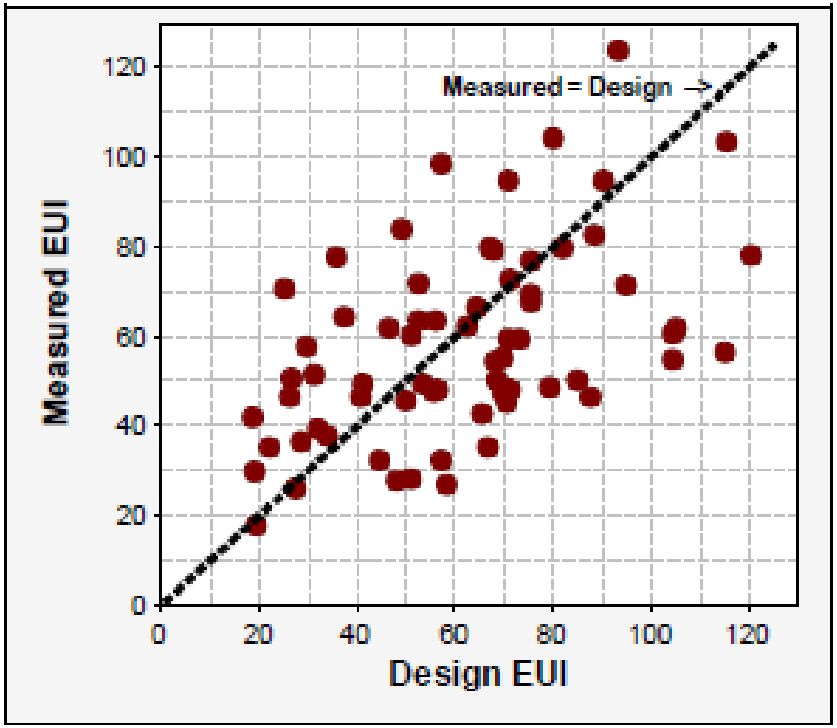
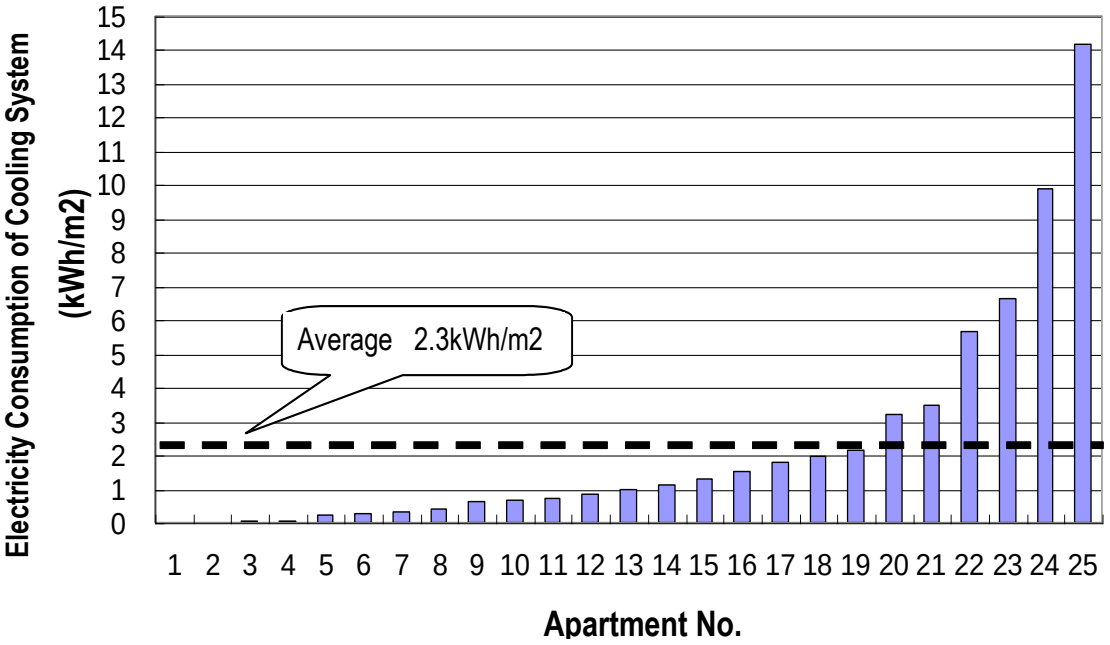


Figure ES- 4: Measured versus Design EUIs
All EUIs in kBtu/sf

Source: NBI report 2008
Energy Performance of LEED
For New Construction Buildings

Background

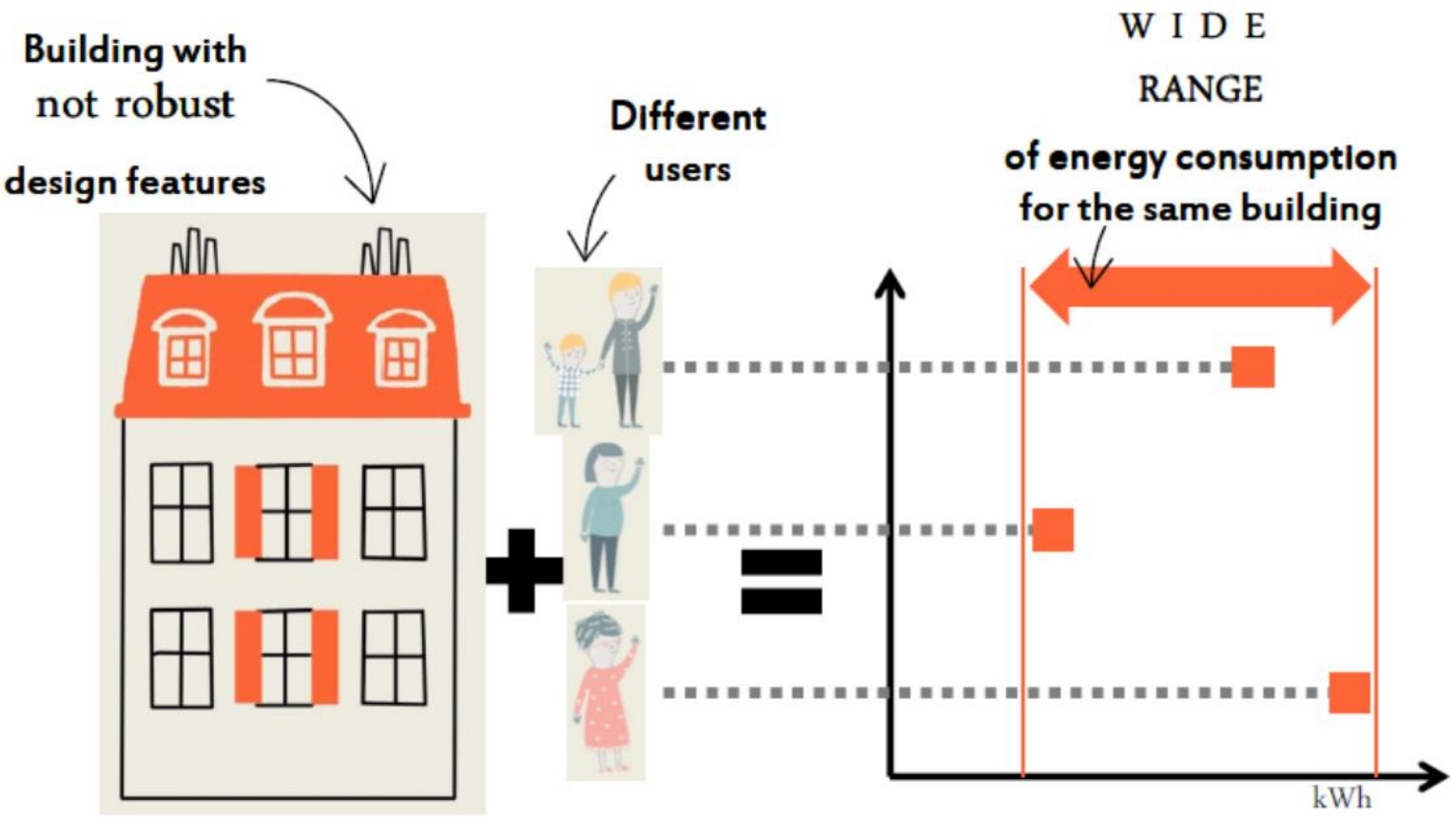
- **OB has significant influence on building energy use**



Significant discrepancy between each apartment

The statistics energy consumption of cooling system in different apartments of one residential building in Beijing,2006

Impact of OB on energy consumption



Stefano Corgnati, POLITO

Impact of OB on EE technology evaluation

What kind of thermal insulation level would be adapted in Shanghai residential building?

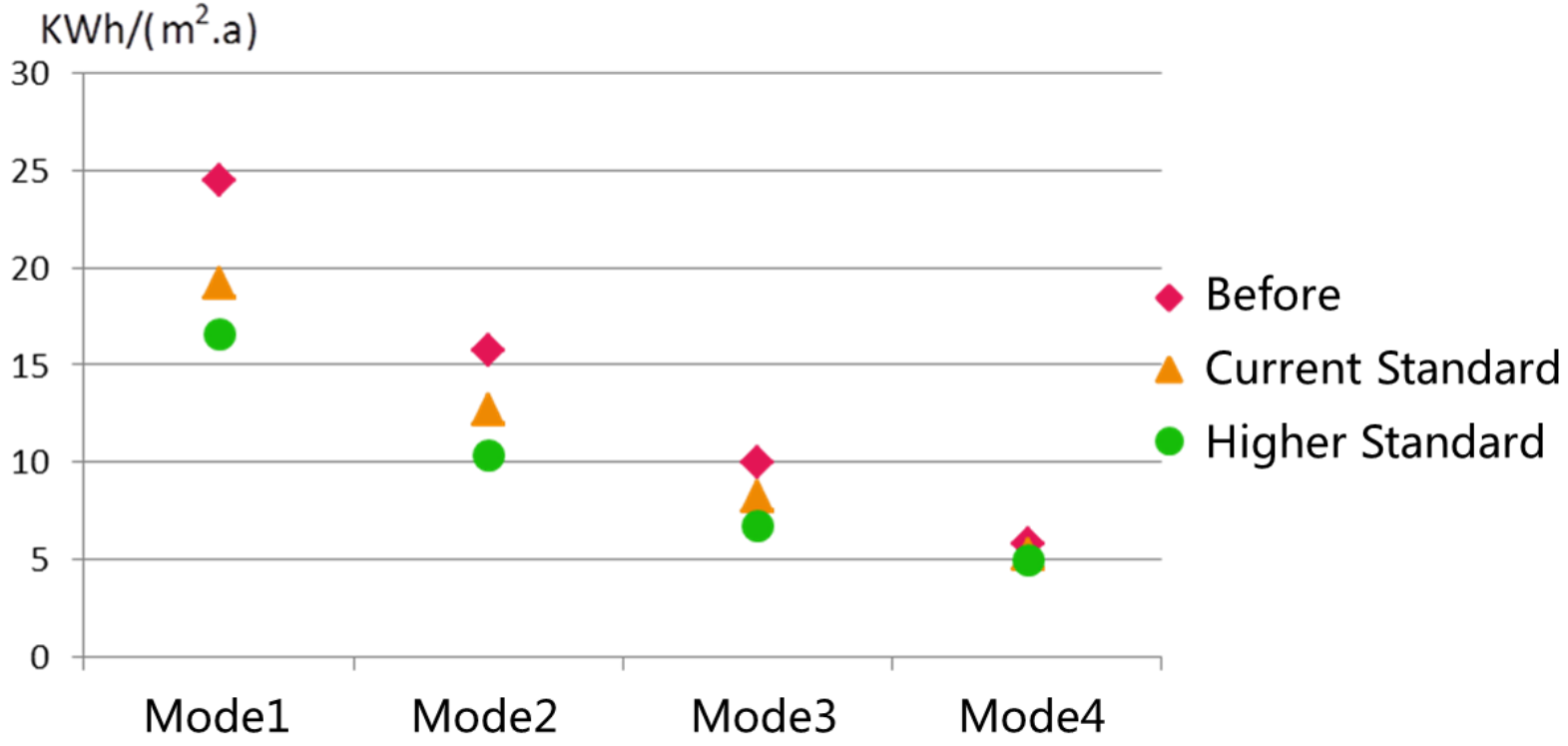
Life Style Mode

	Description
Mode1	Full time full space heating
Mode2	Full time full space heating when Occupied
Mode3	Full time for kids , heating before sleeping for parents
Mode4	heating before sleeping

U Value of building Fabric

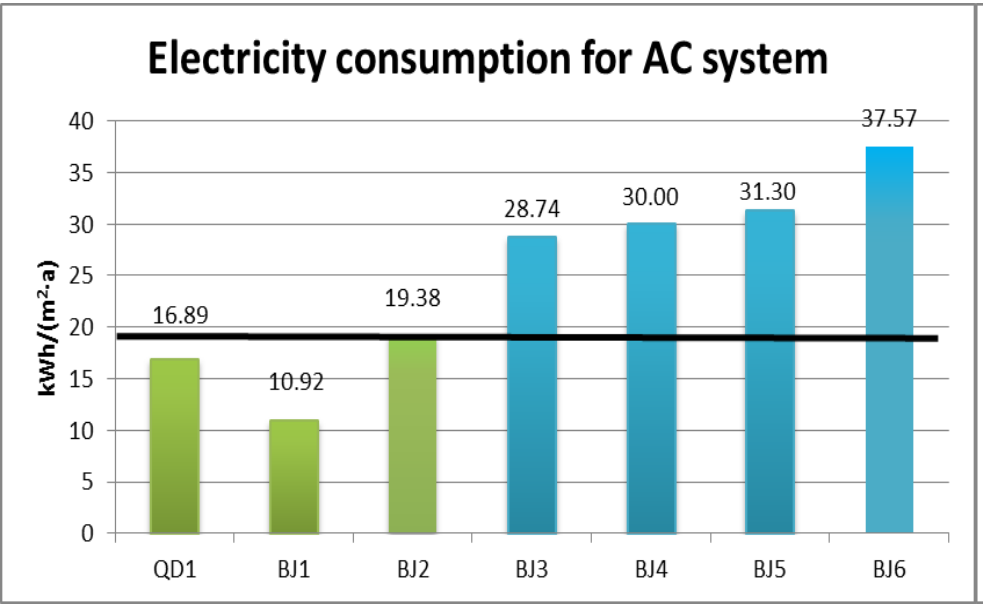
W/(m²·K)	Wall	Roof	Window
1990s	2	1.7	4.7
Current	1.5	1.1	3.2
Japan	0.45	0.45	4.65

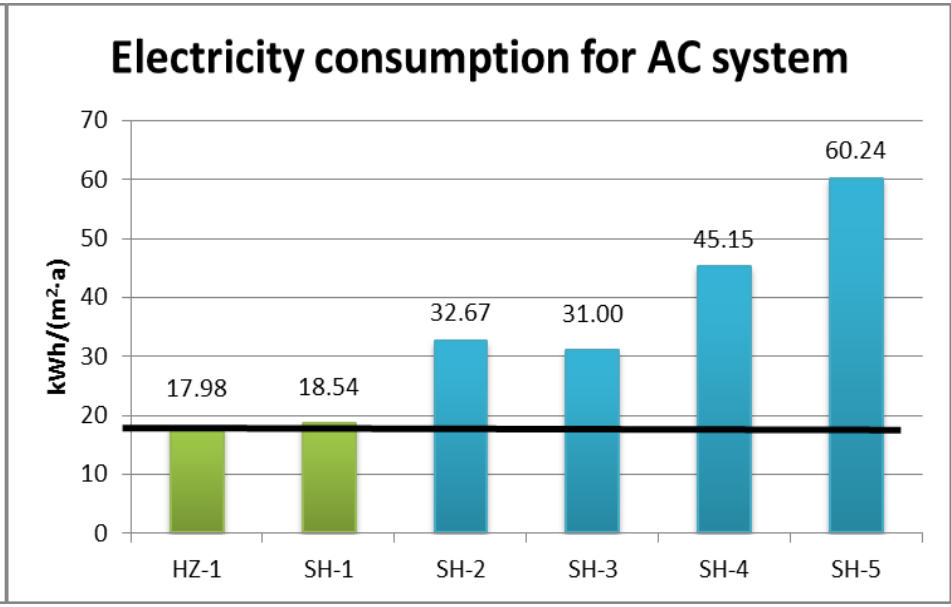
Impact of OB on EE technology evaluation



OB is a key factor in the evaluation of building technology

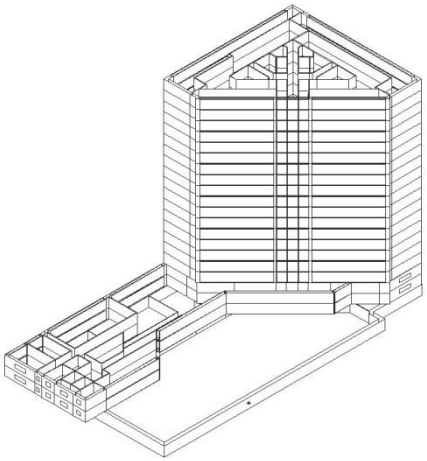
Impact of OB on EE technology evaluation

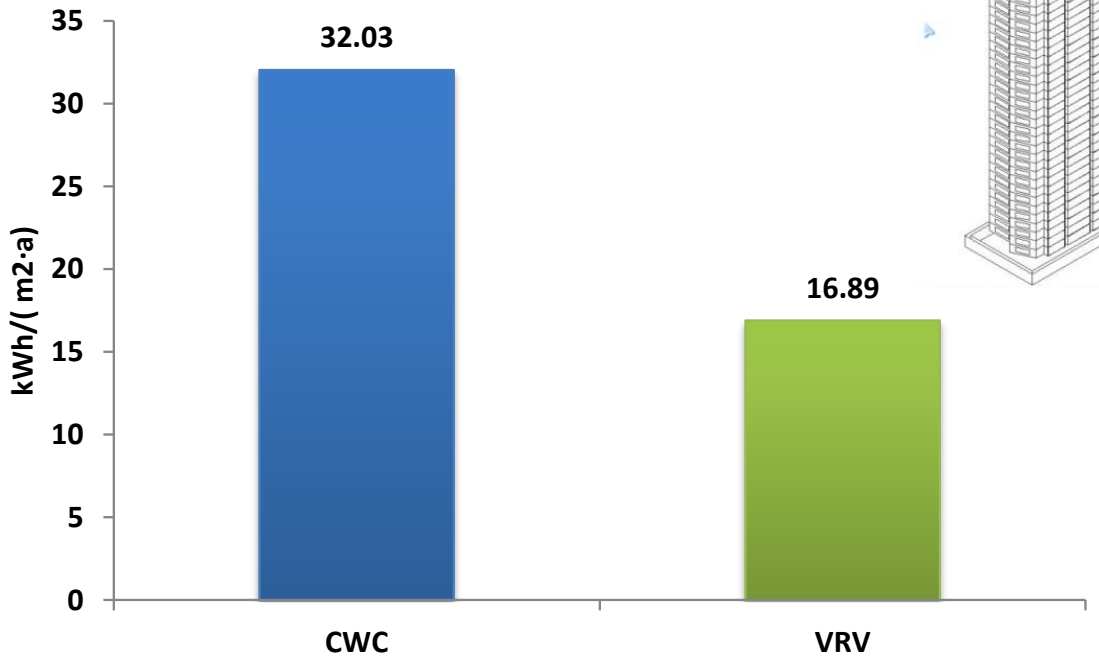


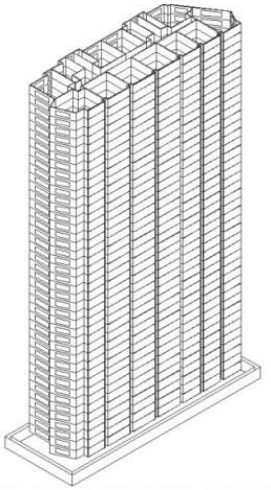


- **VRV system consumes less energy in both Beijing and Shanghai area**
- **But, VRV's COP is at the same level of central cooling system**

Impact of OB on EE technology evaluation



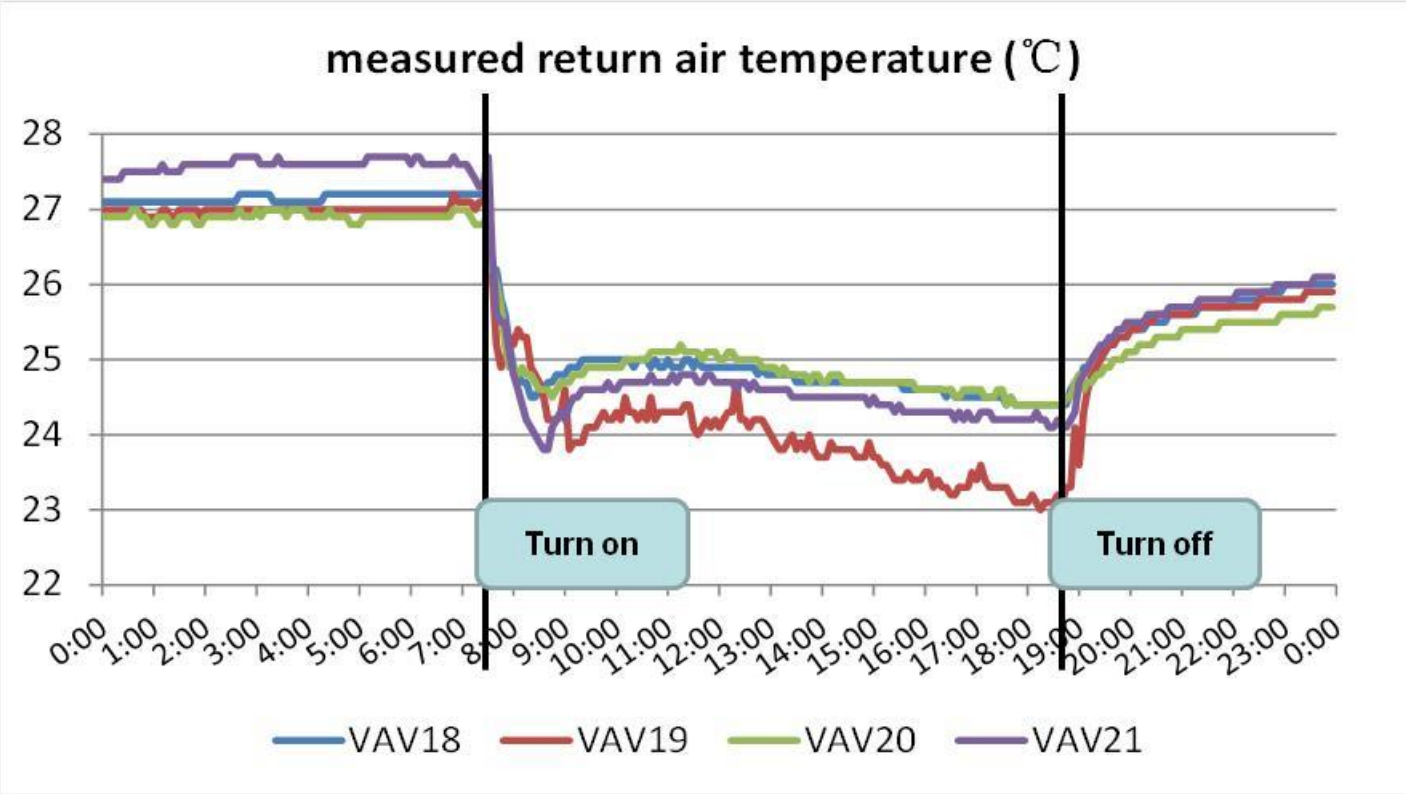




Measured BEC for cooling in two Buildings, 2010

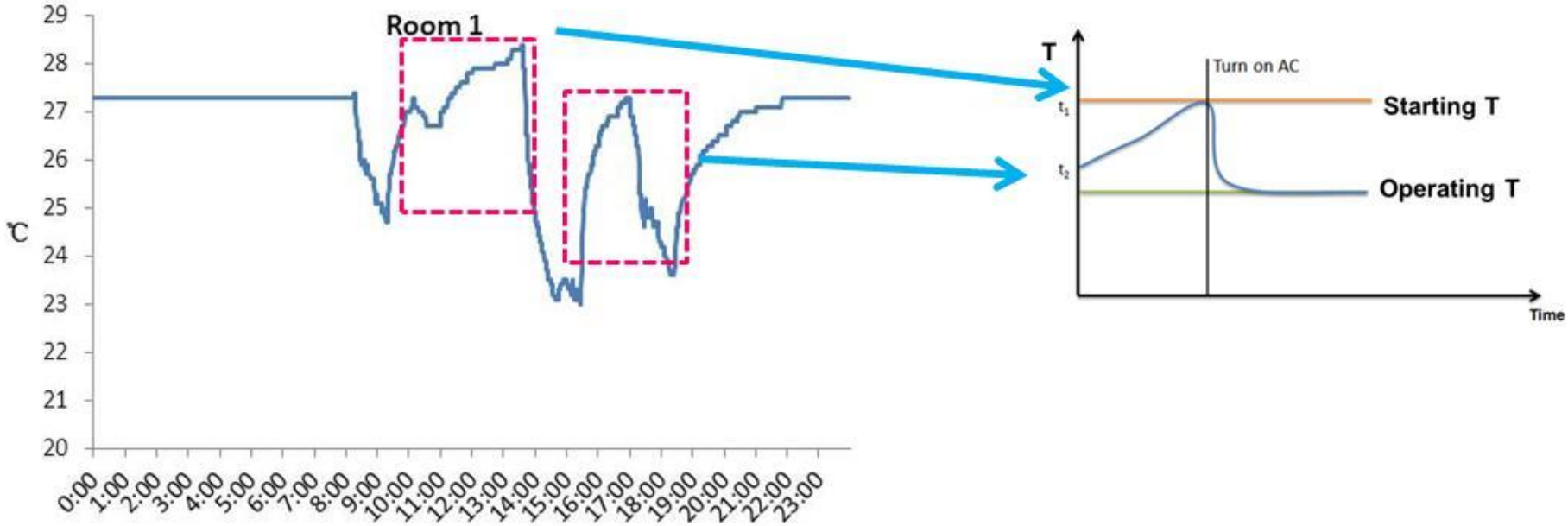
Impact of OB on EE technology evaluation

- **CWC system: use AC system almost all rooms at the same time**

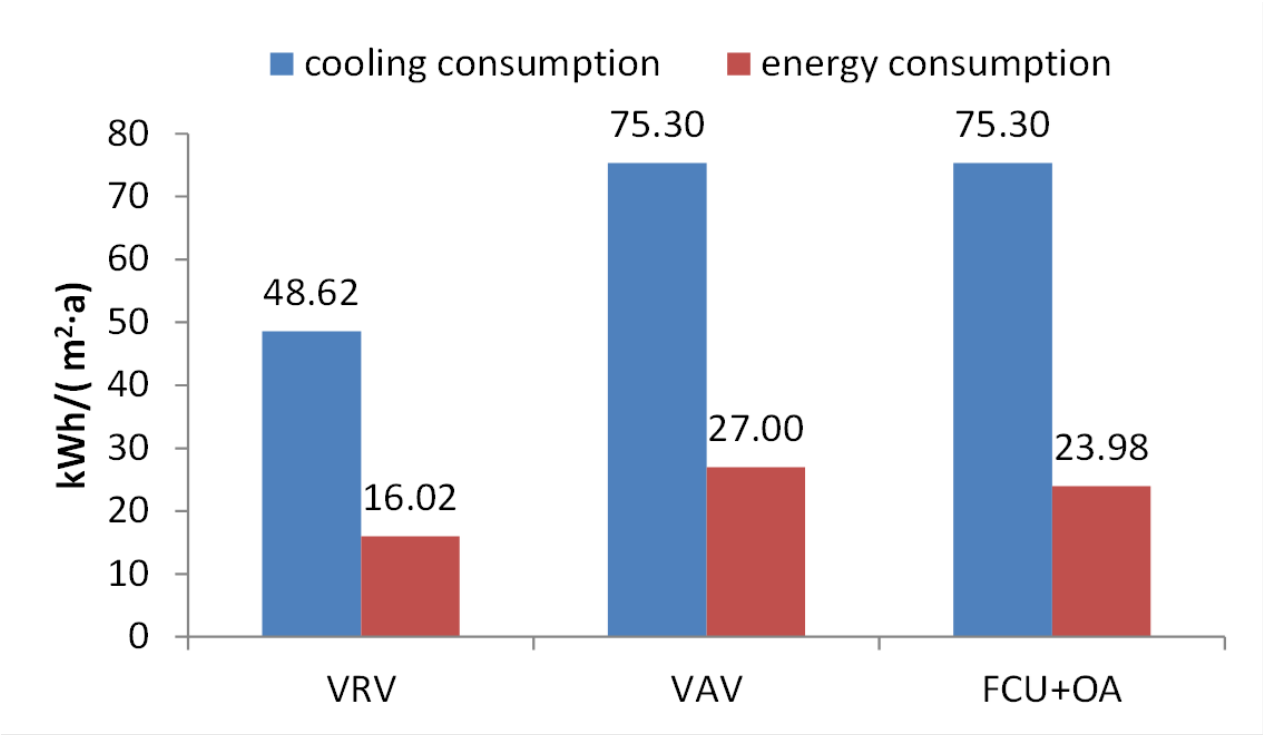


Impact of OB on EE technology evaluation

- **VRF system: use AC system in a part time part space way**



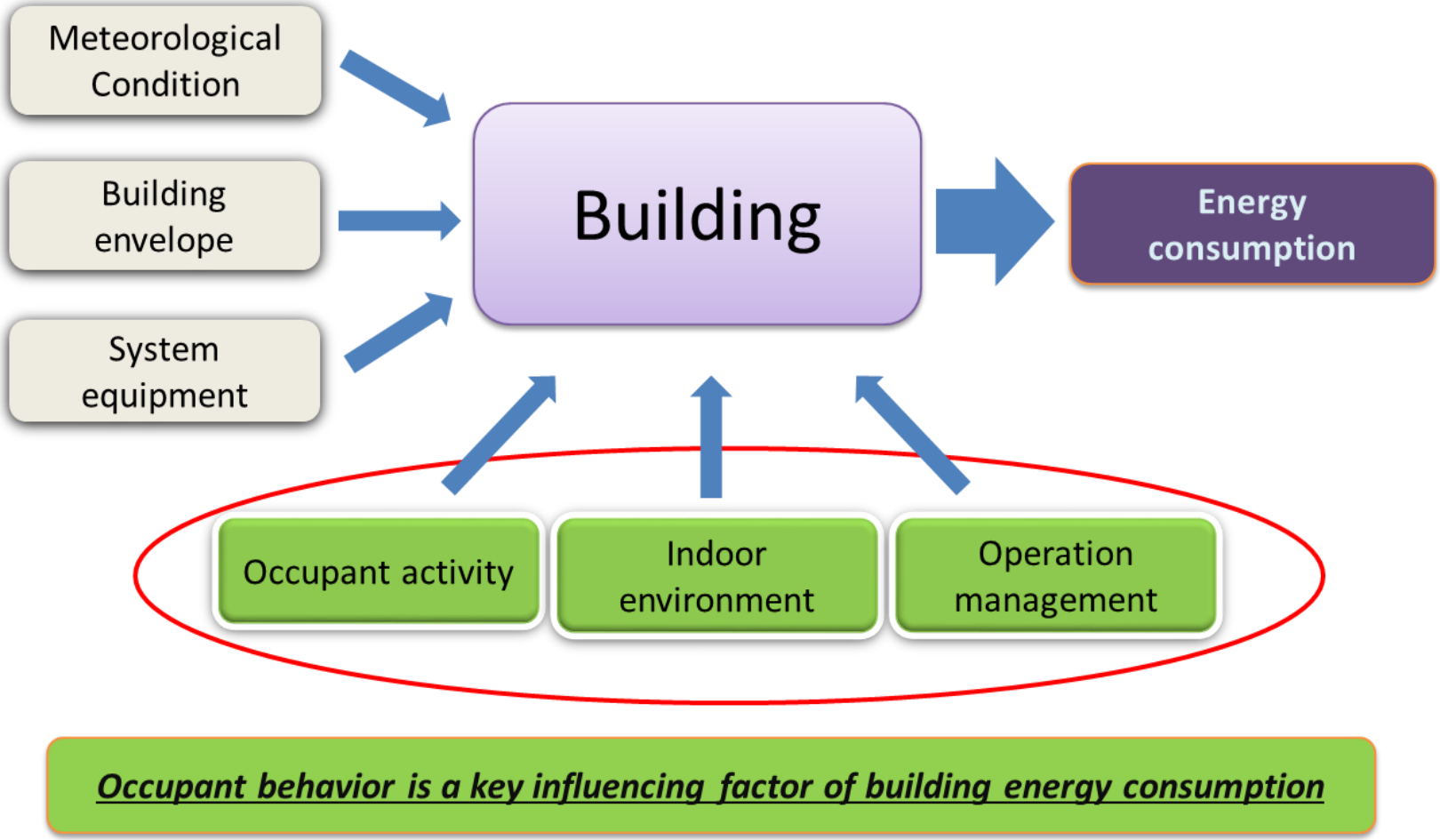
Impact of OB on EE technology evaluation



SCOP	3.0	2.8	3.1

- **The VRF system consumes less energy not due to higher COP, but provide the users more authority to control and adjust their rooms.**

Background



Occupant behavior is a key influencing factor of building energy consumption

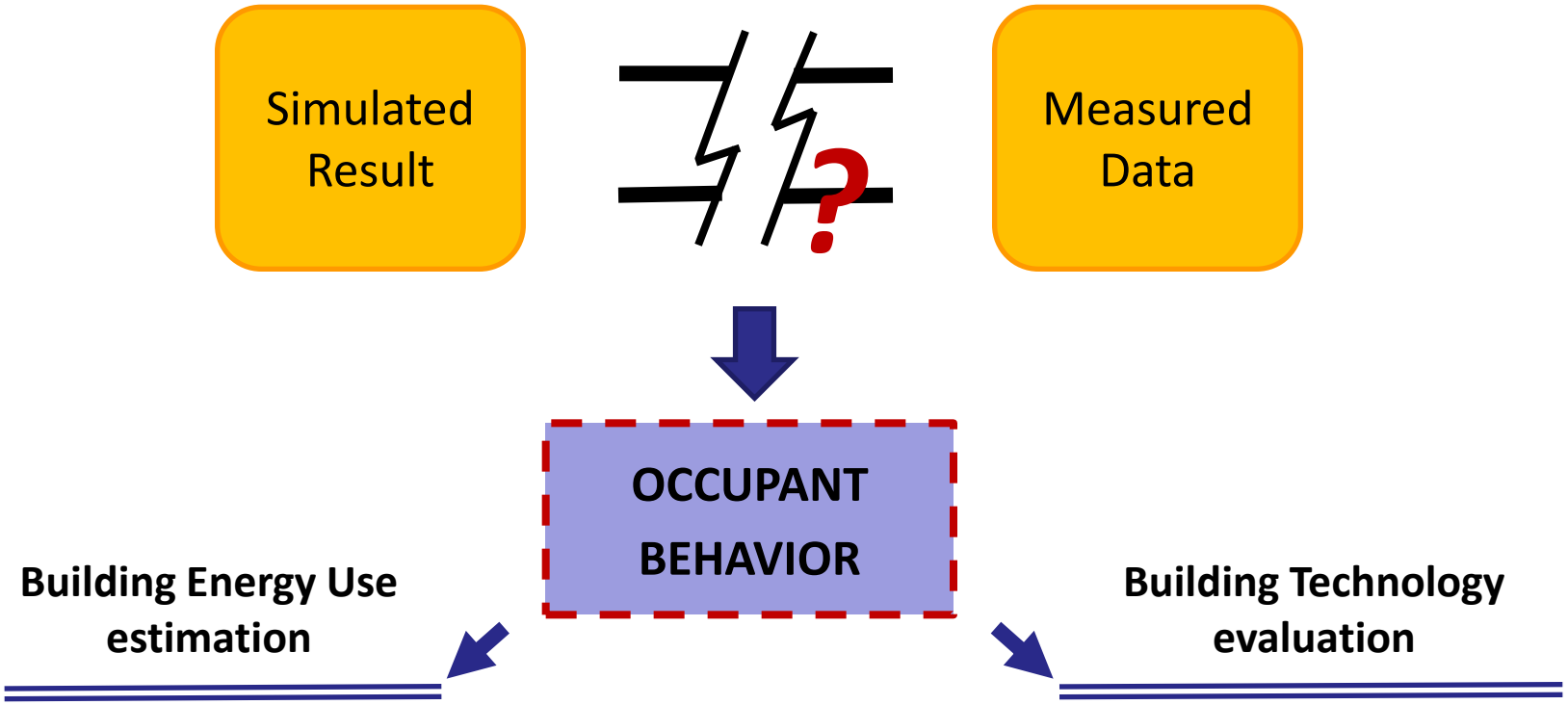
Interaction between OB with system

- Employees are encouraged to **wear a tie** in their office during winter in Hong Kong, to have lower indoor temperature setting to save energy
- Nevertheless…
- Due to internal heat gains, the office continuously supply cooling during winter time
- The **lower indoor set point** will induce to **higher energy consumption**
- There are quite a lot integration and interaction between building fabric, occupant behavior and mechanical system
- We need a methodology to **quantitatively measure** the occupant behavior's effect on total energy usage in building

Importance and Urgency

- OB is a **Key factor** for design optimization, energy diagnosis and performance evaluation, and also building energy simulation
- Limited understanding or inadequate over-simplification on OB;
- **In-depth quantitative analysis** urgently needed;
- Over 20 groups all over the world studying OB individually
- **Lack of consensus** in common language, in good experimental design, and in modeling methodologies.
- An international cooperation is extremely important for both knowledge gaining and data sharing

Importance and Urgency



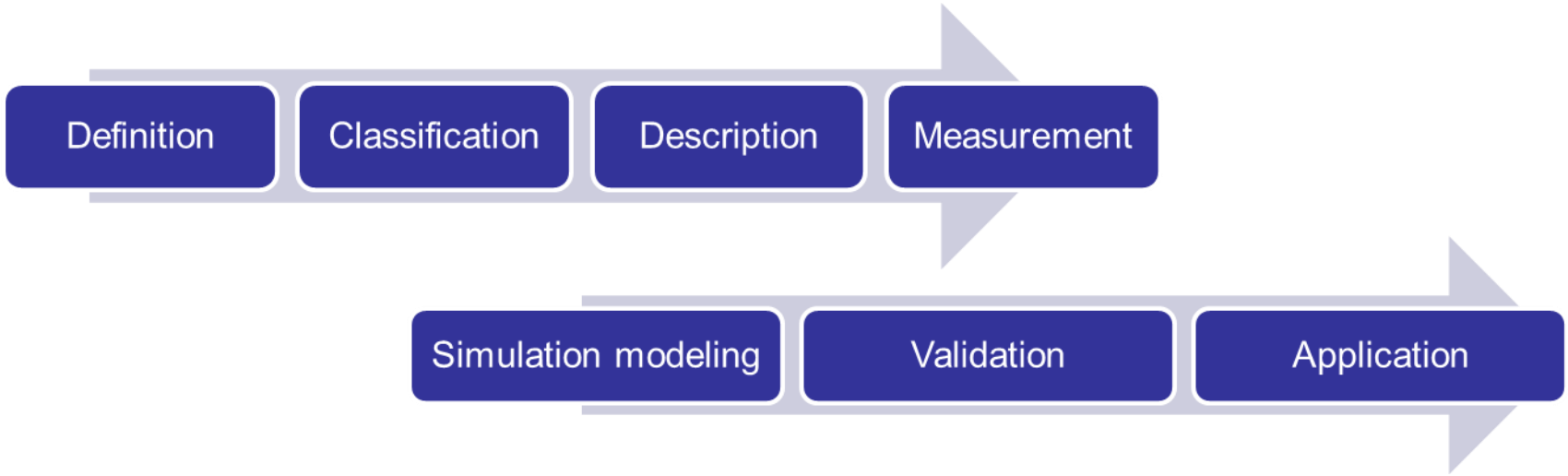
IEA-EBC-ANNEX66 Definition and Simulation of Occupant Behavior in Buildings

www.ANNEX66.org

Research Target

- Identify quantitative definition, description and classification of OB
- Develop effective simulation methodologies of OB
- Integrated OB models with building energy simulation tools
- Demonstrate the OB models in design, evaluation, operation management and policy making by case studies

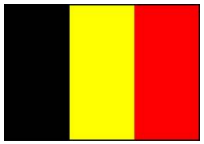
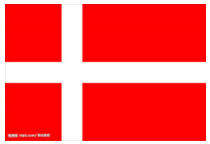
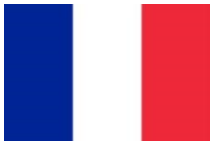
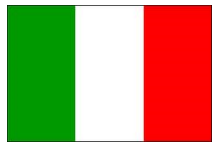
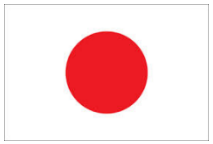
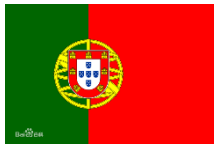
Research Target



- **Quantitative methods & common language for OB description and simulation**
- **Develop a scientific framework for OB quantitative definition and simulation methodologies**

Participants

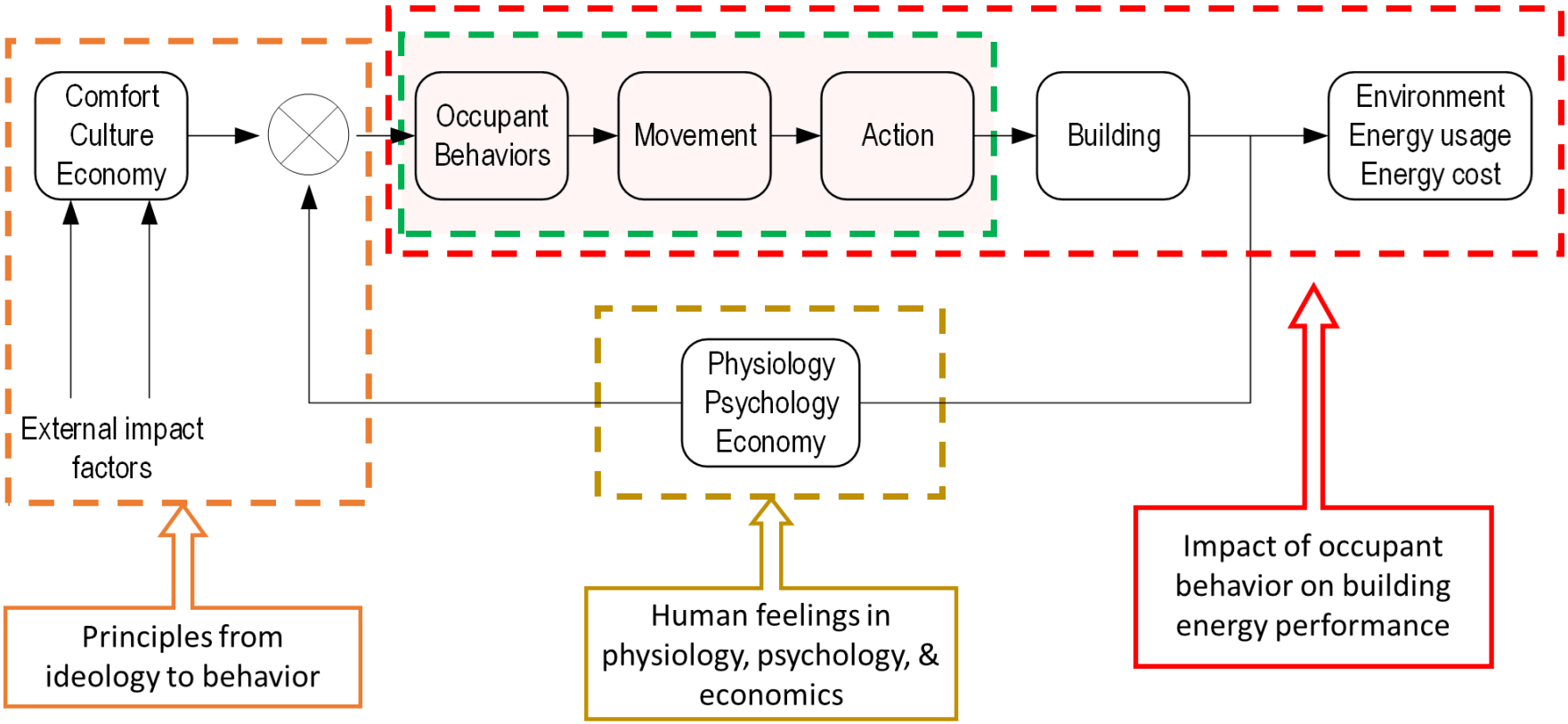
24 Countries

					
Australia	Austria	Belgium	Brazil	Canada	China
					
Denmark	Finland	France	Germany	Hungary	Italy
					
Japan	Korea	Netherland	Norway	Poland	Portugal
					
Spain	Sweden	Singapore	Turkey	UK	USA

Participants

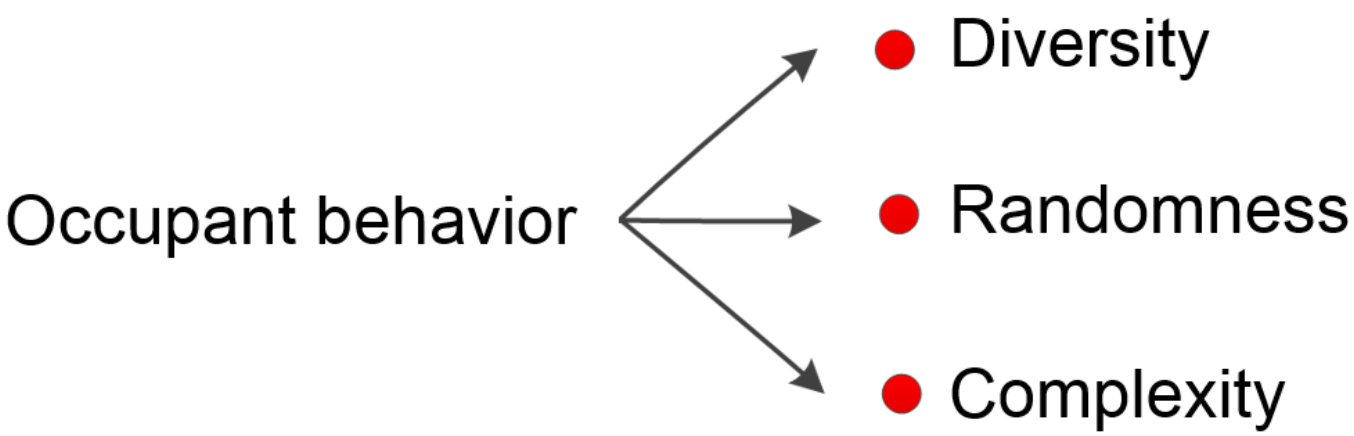
- 24 Nations, 69 institutions
- 114 participants, plus 13 participants want to be kept informed
- University, research institute, software company, design consultant company, operation manager, system control company
- ASHRAE has confirmed to join this project, IBPSA, REHVA and CIBSE are considering participation

Scope



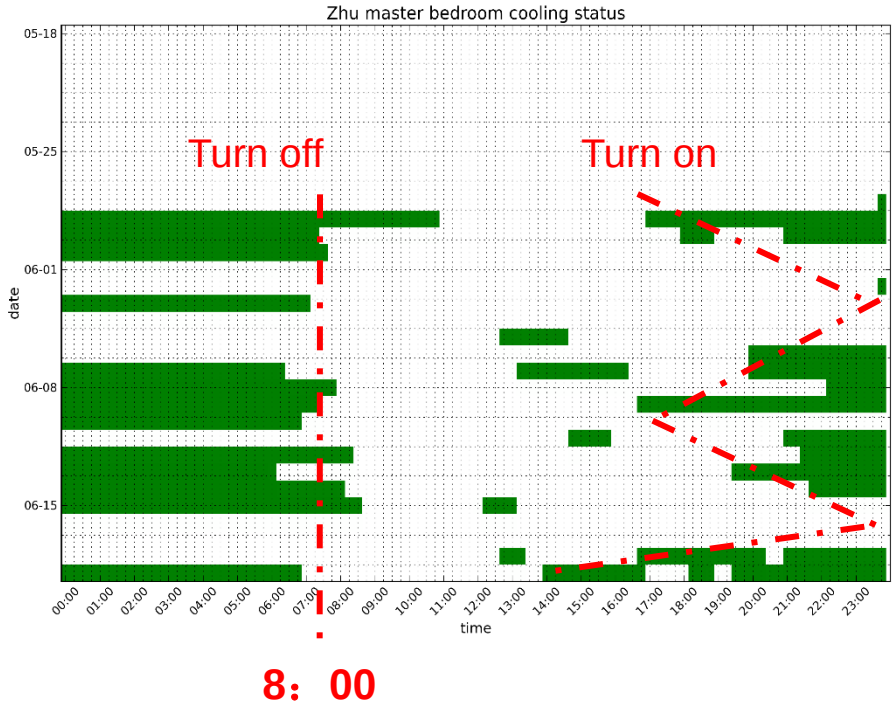
Focus on how OB physically and quantitatively affect on building performance simulation

Challenges



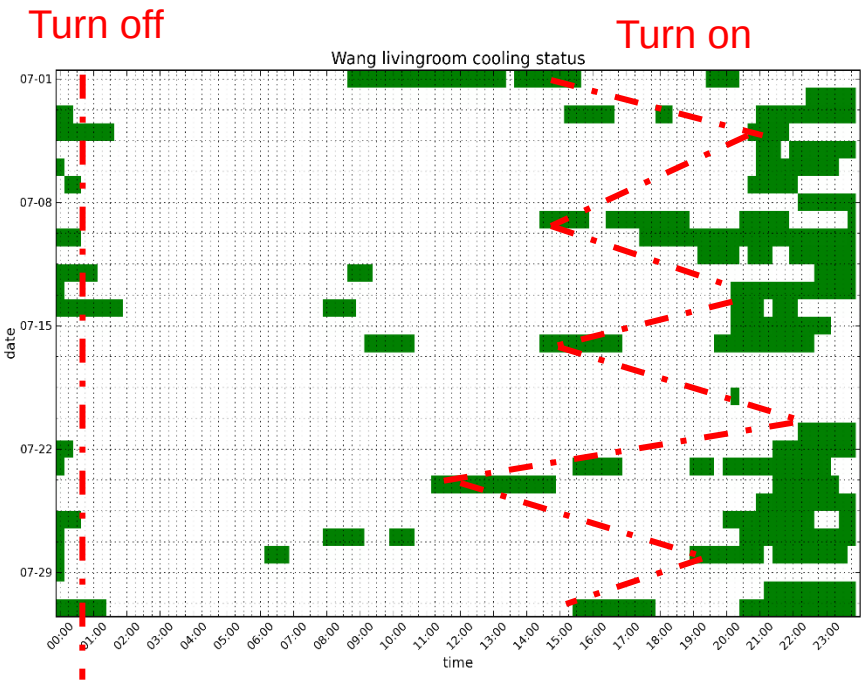
Stochastic process

- Zhu, 2011/5-6



8：00

- Wang,2011/7



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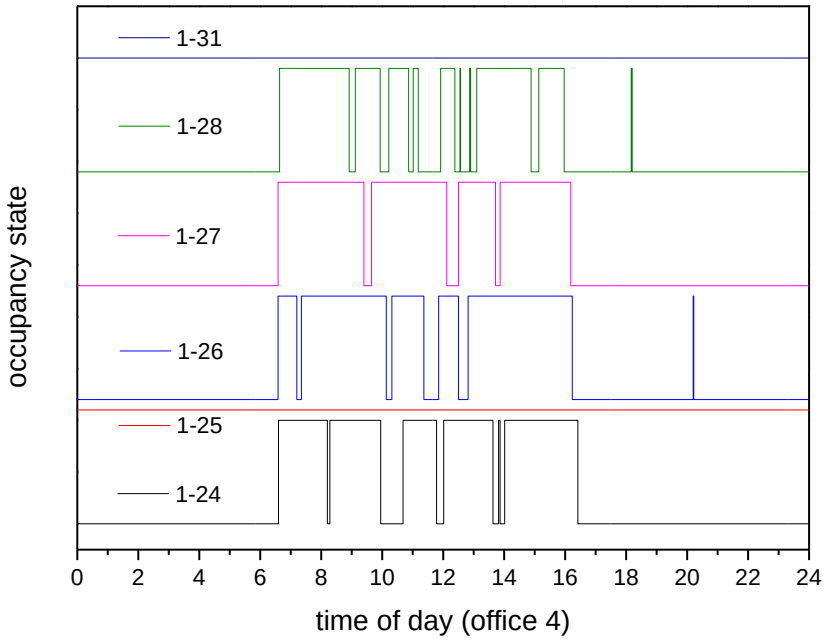
ON

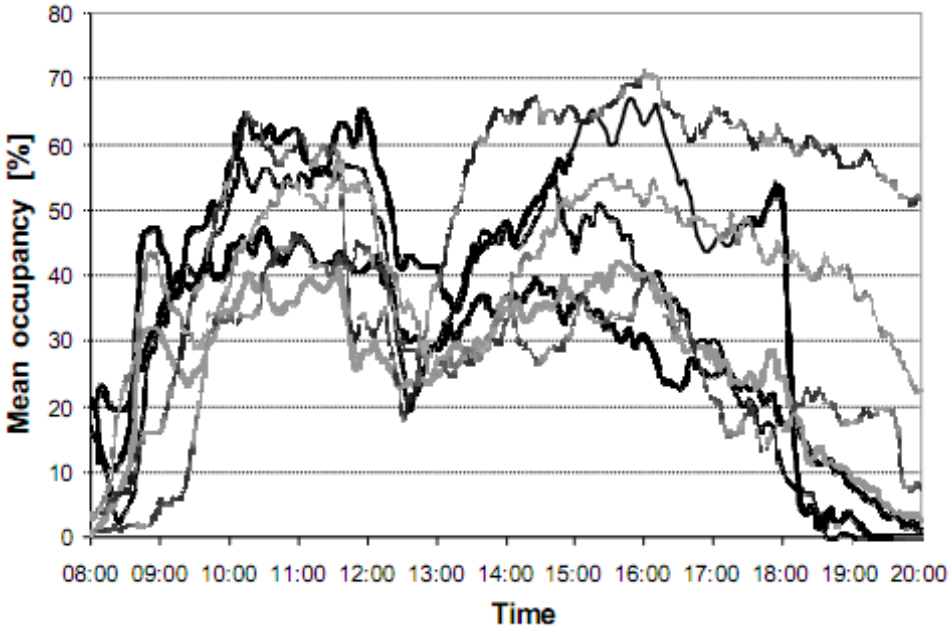
OFF

Stochastic process

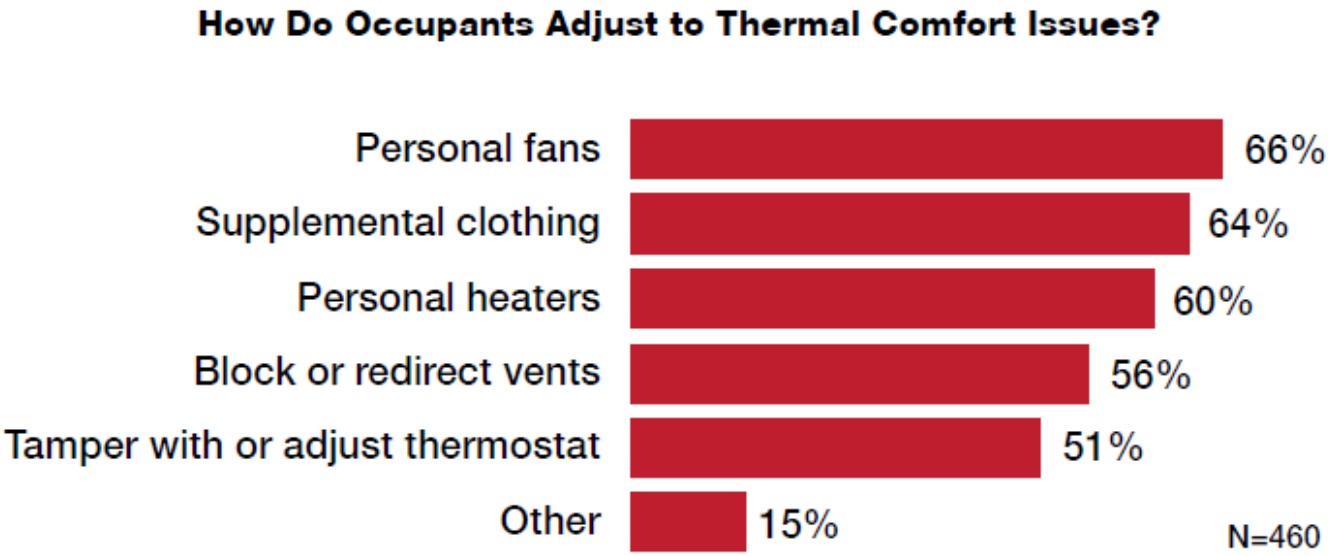
Personal level



Building level



Diversity

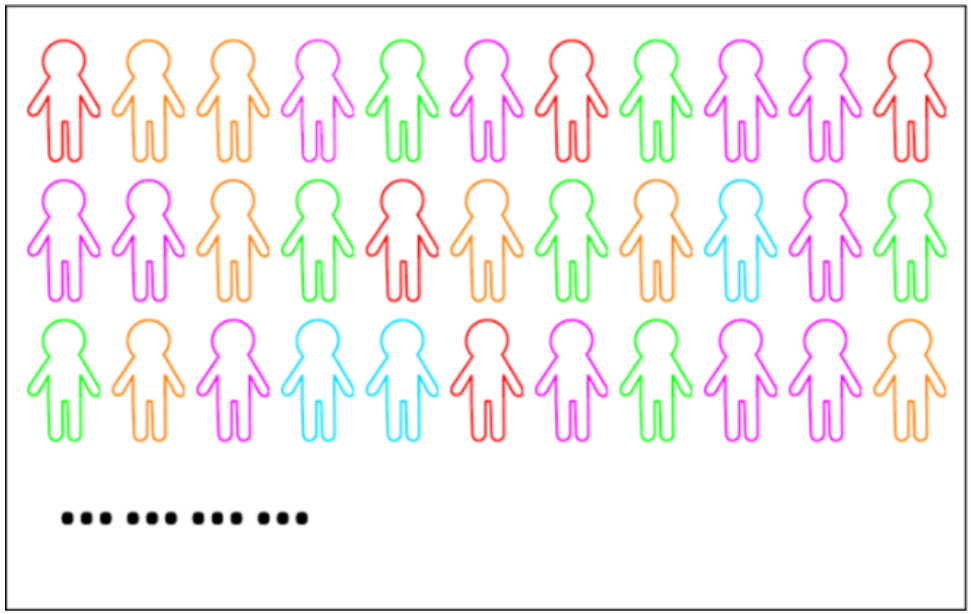


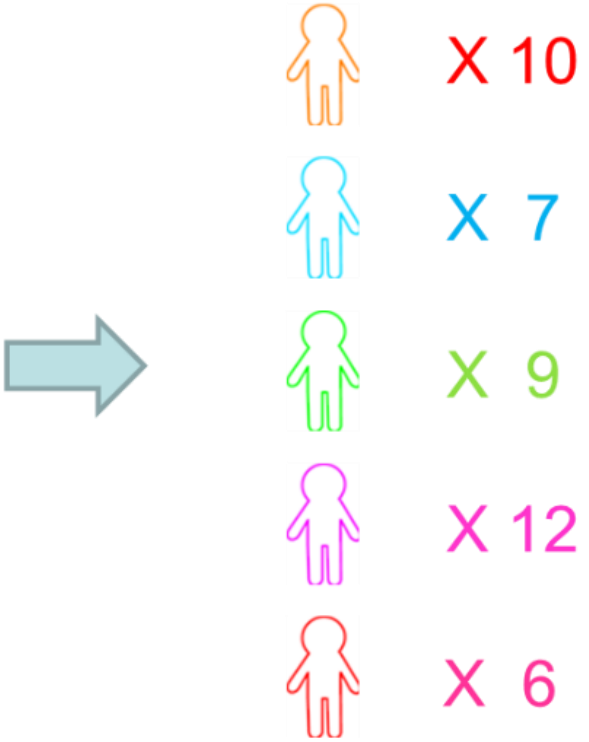
Other responses include: complain, contact facilities department, keep blankets and sweaters within reach, and open windows.

IFMA 2009 HVAC Survey of IFMA members in US and Canada with 452 responses from 3357 samples

Diversity

- A so called **“typical persons”** and their distribution are essential to connect between the academic research and policy making





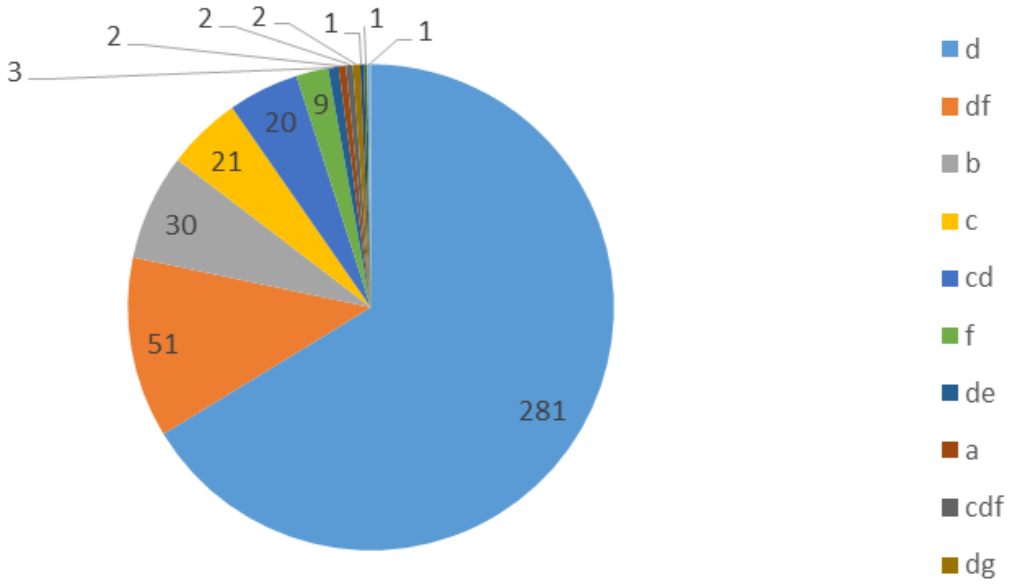
Complexity

- **Behavior may be triggered by multiple factors for an individual**
- **And behavior would interactive with each others**

Questionnaire survey results in Chengdu

Opening mode	
a	Never on
b	Always on in summer
c	On as long as entering
d	On feeling hot
e	On regular at ___ o'clock
f	On when guests come
g	Others

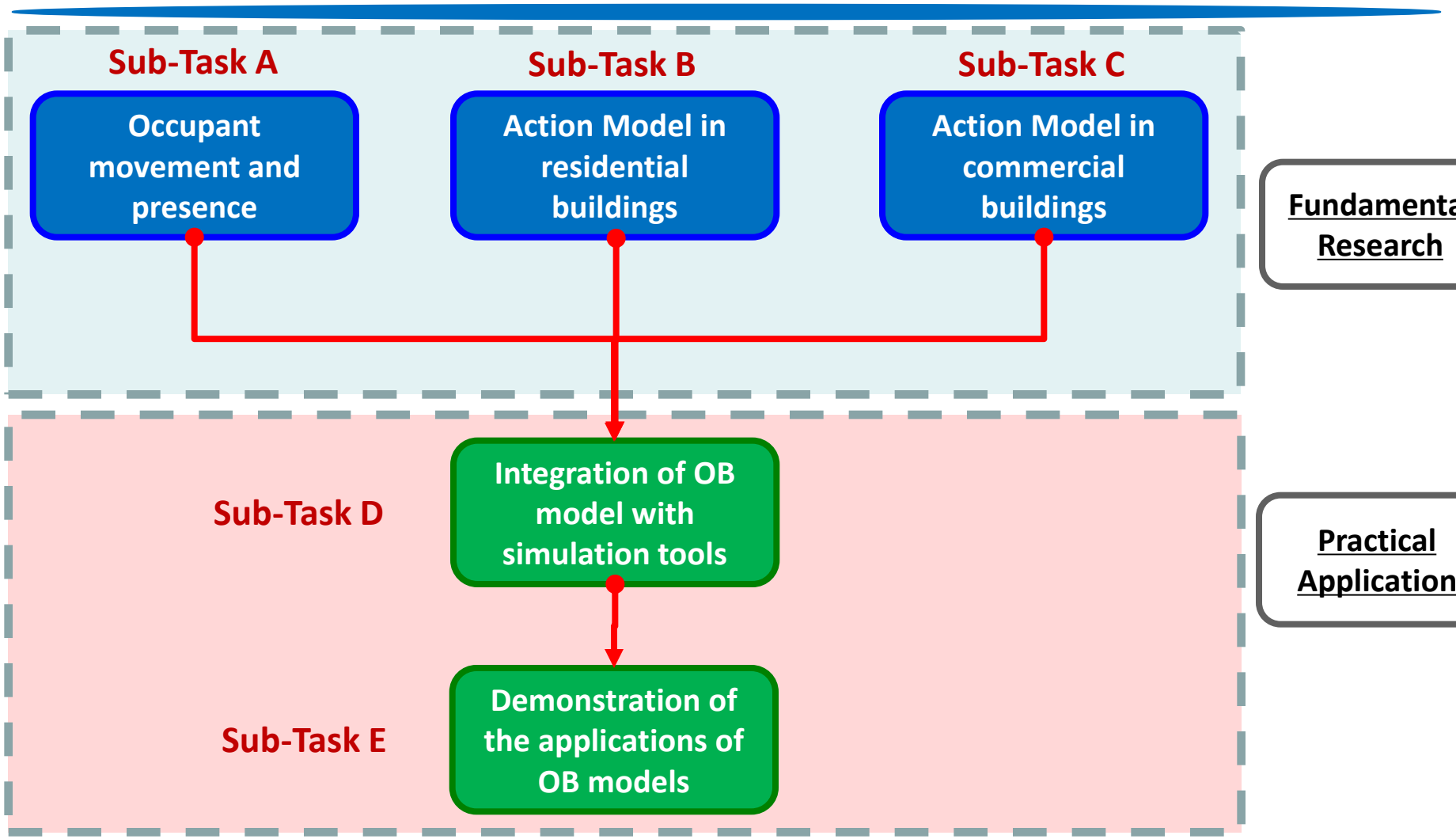
AC Operating Modes in Living-room



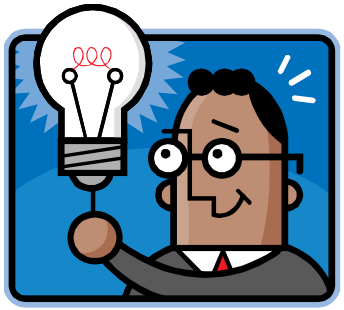
Technical approach

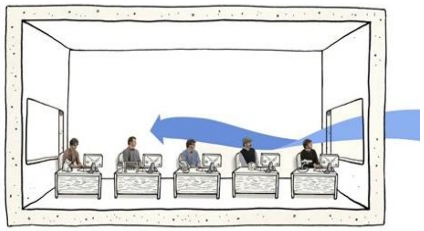
Targeting Building types:

Residential buildings & Office buildings



ST-A Occupant presence and movement model





Occupant
Presence & Movement

Occupant's presence and movement is strongly connected with Space, Time and Events

ST-A Occupant presence and movement model

Building level – # of occupants

- Q: How many occupants are there in a building at a time?

Space level – occupied status

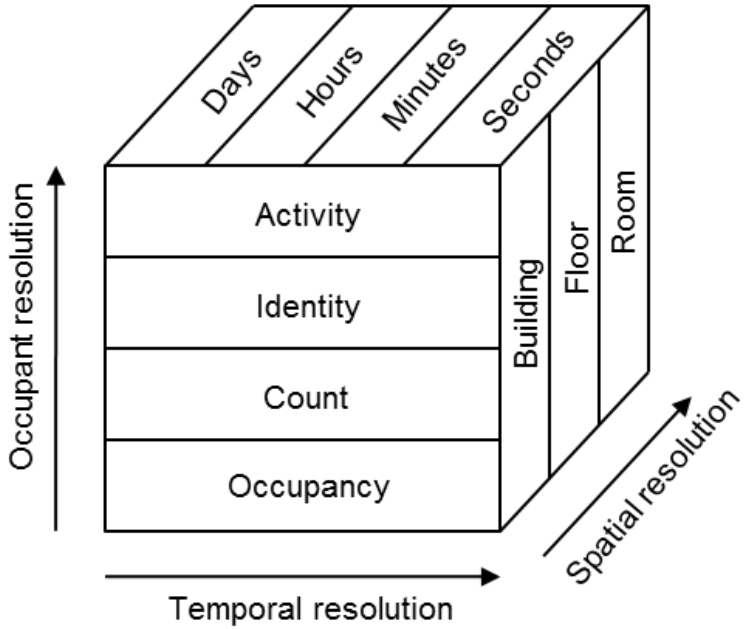
- Q: whether or not a space (room) is occupied?

Space level – # of occupants

- Q: How many occupants are there in a space at a time?

Occupant level - individual tracking

- Q: In which space an occupant is at a particular time?



A set of coherent occupant presence models are demanded for different application purposes

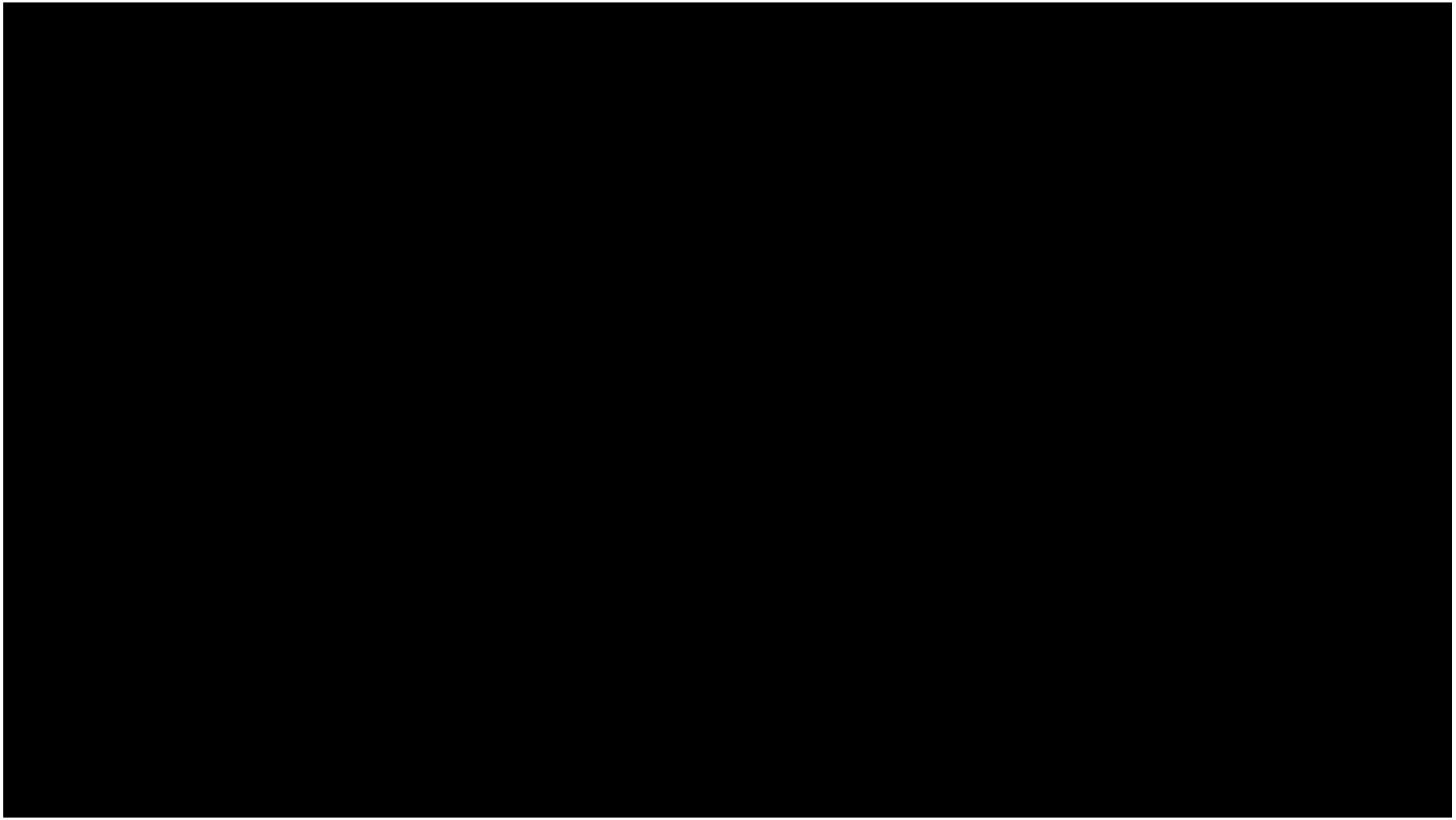
Example of Occupant Movement Model

Characteristic parameters for movement

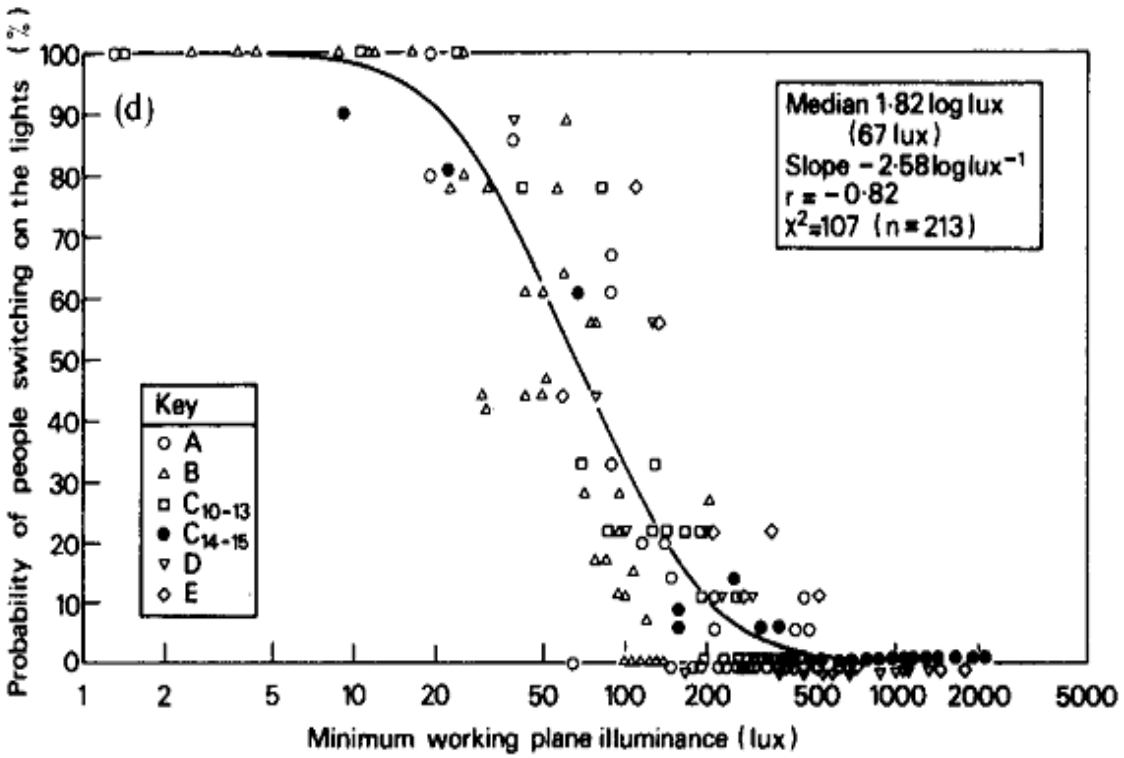
Weekday schedule	Event	Valid Period	Characteristic parameters of occupants		
Working time 8:00~17:00 Lunch time 12:00~13:00	**Go to office**	7:00~8:30	Mean morning arrival time		7:45
	Leave for lunch	11:30~12:30	Mean leaving time		12:00
	Return after lunch	12:30~13:30	Mean return time		13:00
	Get off work	17:00~21:00	Mean night departure time		18:00
	Walk around	8:00~17:00		proportion of time	mean sojourn time in room
			In own office	0.93	3h
			In other rooms	0.06	10min
			In outside	0.01	10min
	Meetings	8:00~17:00	*See table for meeting rooms*		
	Close	23:00	Closing time		23:00

Type of meeting room	Occupied time proportion	Mean duration per time	Minimum attendees	Meeting type	
Meeting room	0.2	1h	2	Group meeting	2/3
				Mixed	1/3

Demo. of simulation results

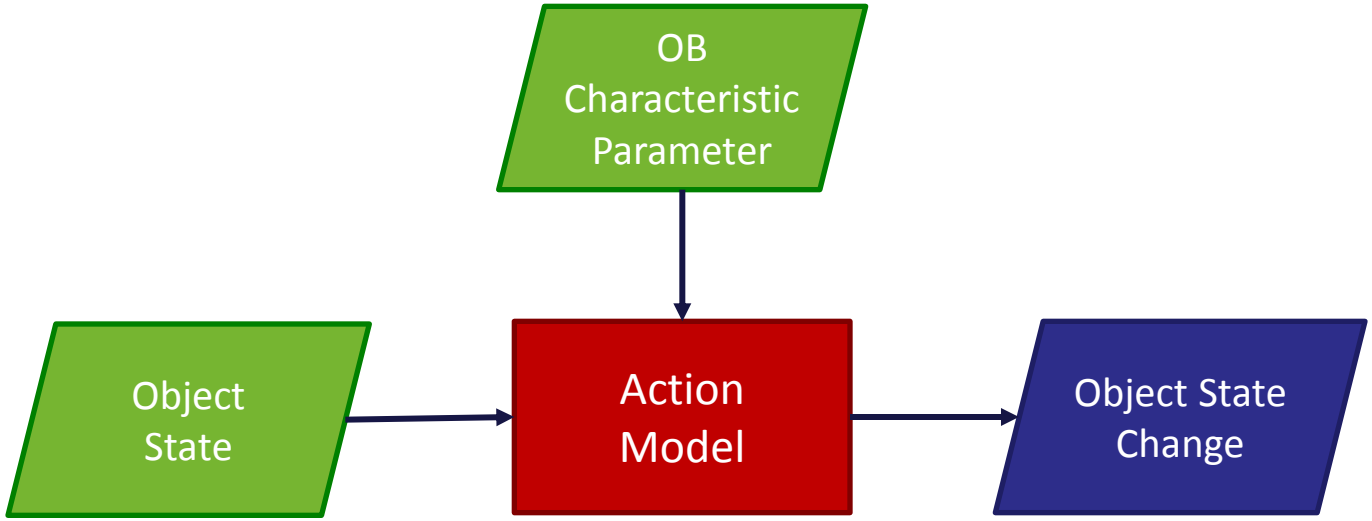


ST-B Action model in residential buildings



Occupant's actions are influenced by environmental and physical parameters in a stochastic way

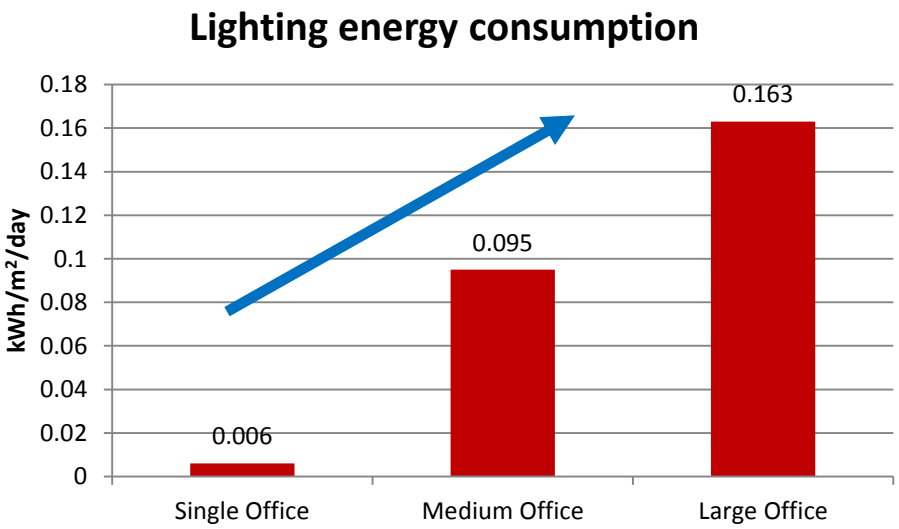
ST-B Action model in residential buildings

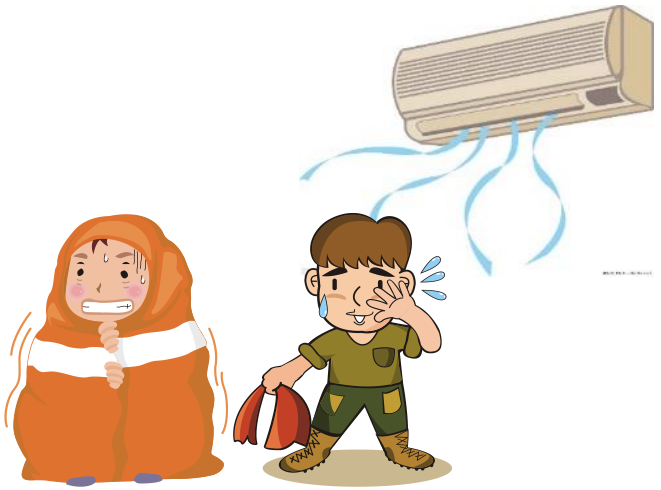


State based → Action Based

Action based models has more advantage to exhibit the relationship between OB phenomenon and physical driven force

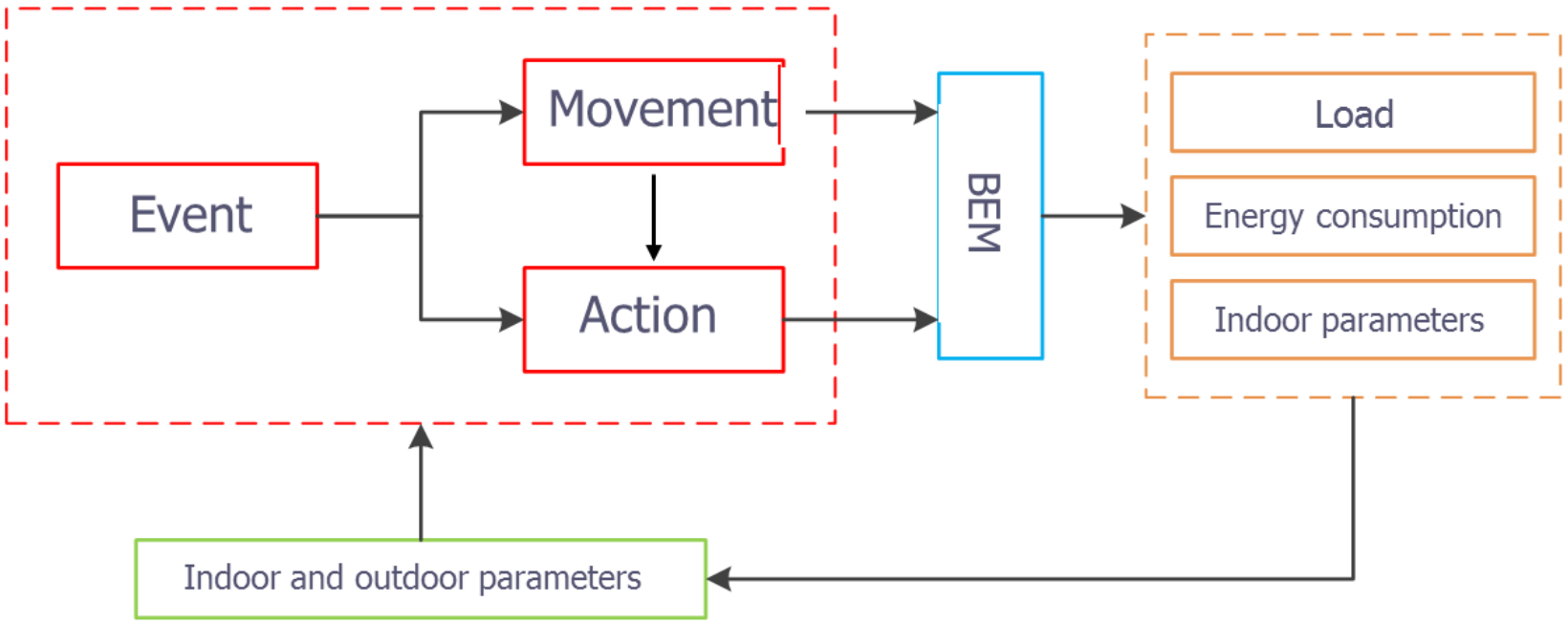
ST-C Action model in commercial buildings



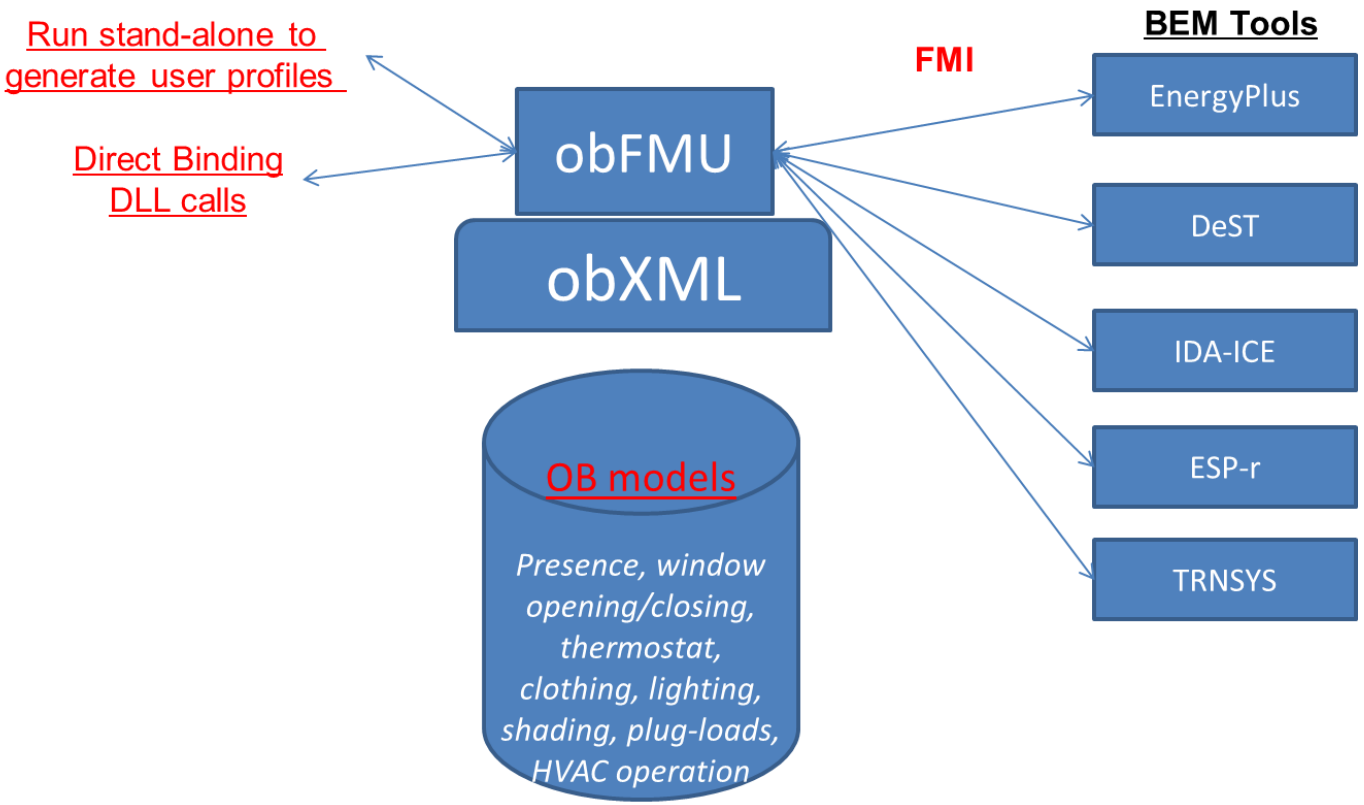


Higher possibility of interaction and negotiation among occupants in commercial buildings

ST-D Integration with simulation software

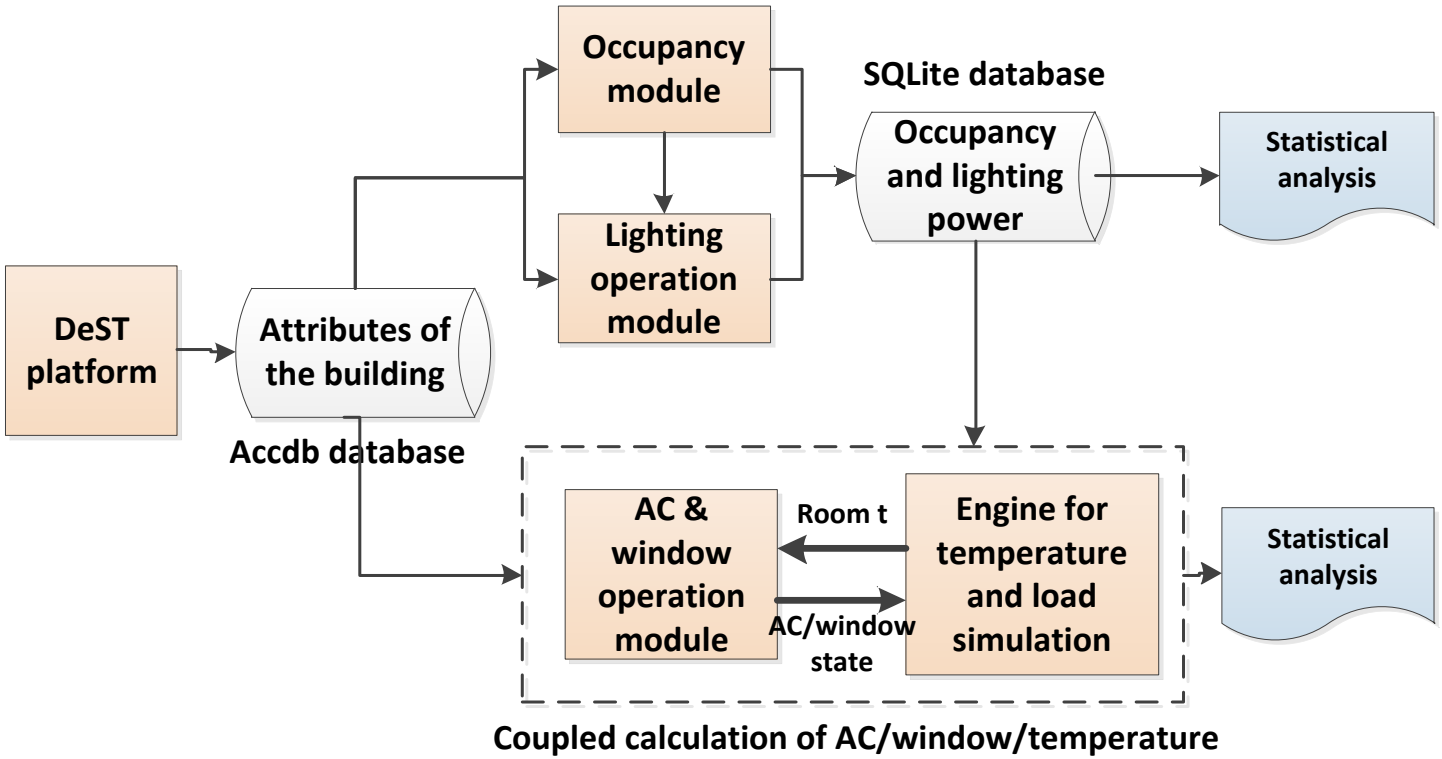


ST-D Integration with simulation software



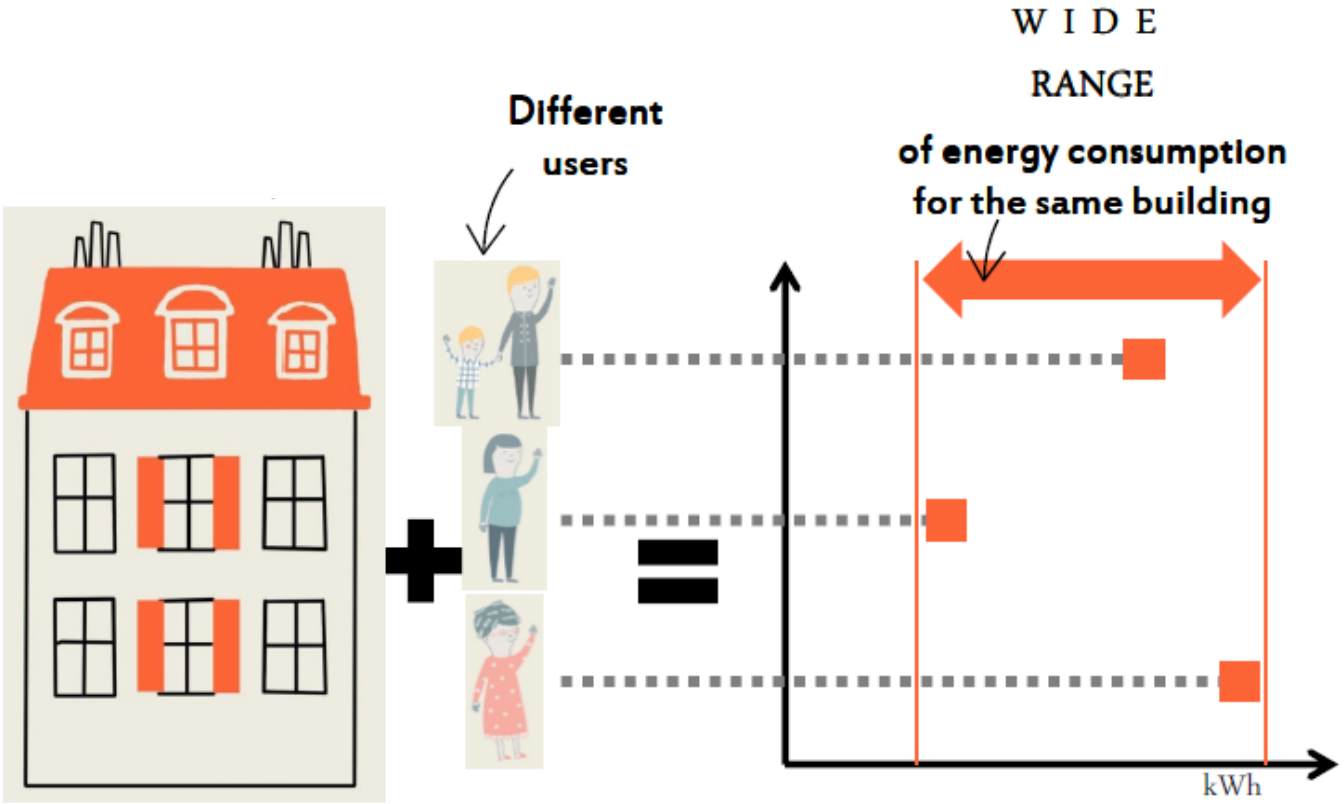
Essential to integrate the OB models with BEMs to exhibit the influence of OB on building energy and performance

ST-D Integration with simulation software



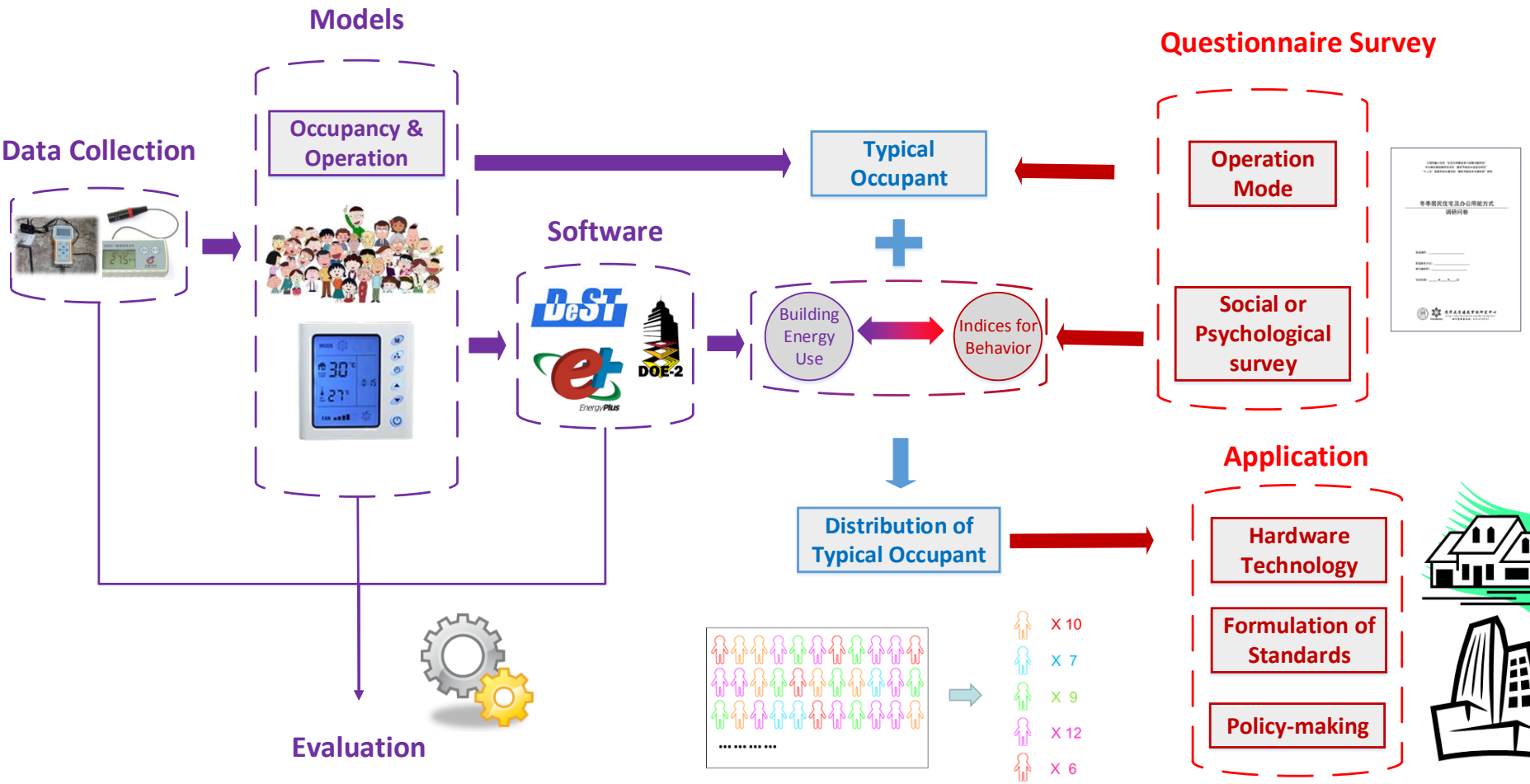
Develop flexible, sustainable, robust module for simulation

ST-E Applications of OB models

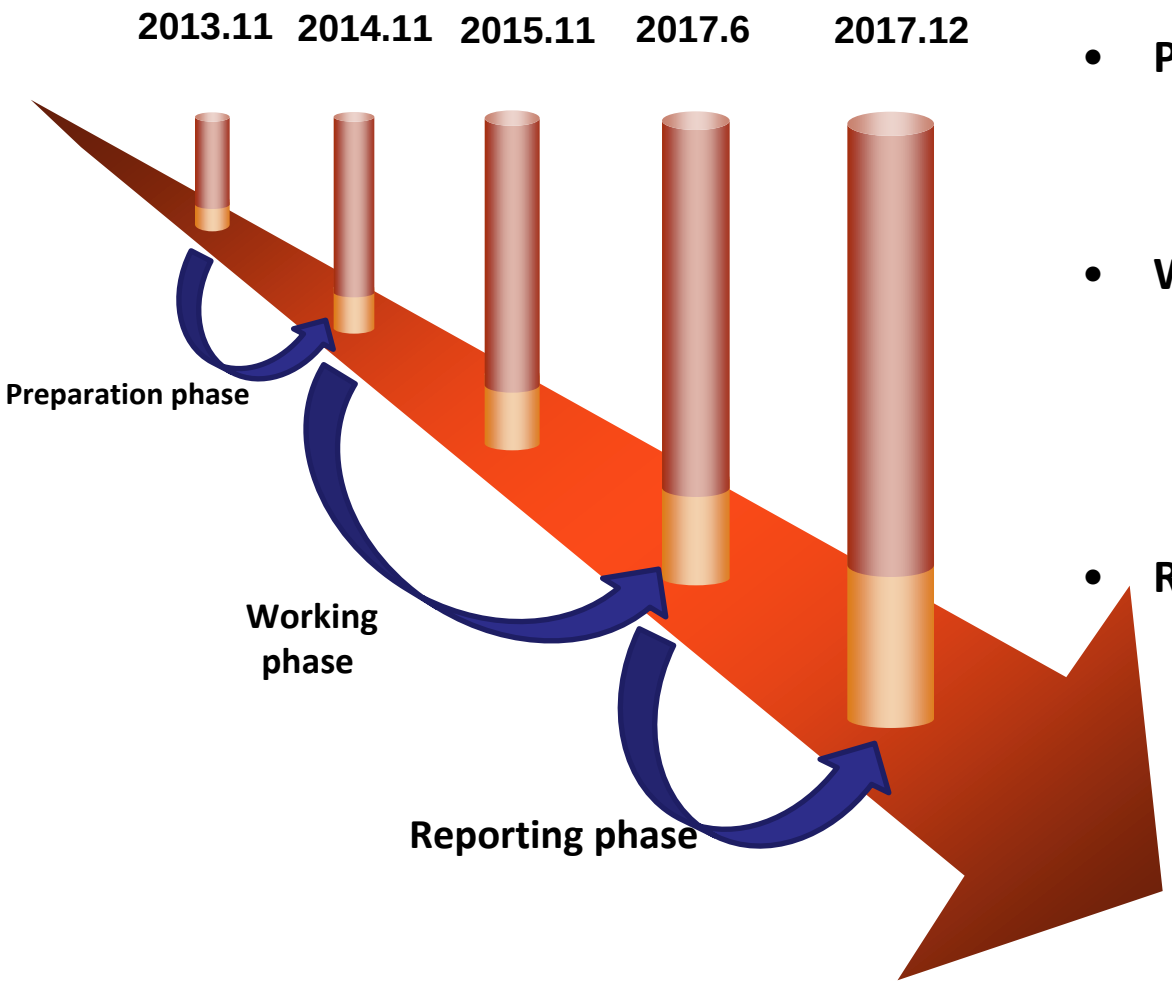


To exhibit OB's influence on comfort, environment, energy usage and technology adaptability, improve applications by case studies & guidelines

Outlook of Occupant Behavior Research



Work plan



- **Preparation phase**
  - One year (2013.11 — 2014.11)
- **Working phase**
  - Two and a half years (2014.11 — 2017.6)
- **Reporting phase**
  - Half a year (2017.6 — 2017.12)

Outcomes

	Outcomes	Target Audience
1	Standard definition, description and classification of occupant behaviour in building	**Building Energy Researchers** **Energy Modellers** **Simulation Software Developers**
2	Systematic measurement approach, simulation modelling and validation methodology	
3	Occupant Behavior Database with data of different temporal and spatial resolution	
4	Software to simulate OB, integrated with a building thermal and energy model	**Building Designers** **Energy Saving Evaluators** **HVAC Engineers** **System Operators** **Energy Policy Makers**
5	Case studies and guidelines to demonstrate applications of the new OB definitions and models	

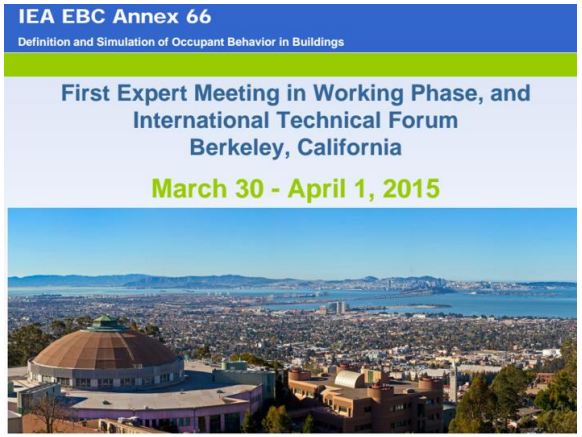
Activities

International Workshop for New ANNEX

Aug. 23rd, 2013, Paris, 24 participant

Seminar at ASHRAE Seattle Conference

About 100 people attended the seminar



1st expert meeting in Hong Kong

March 12 to 14, 2014, 39 participants

2nd expert meeting in Nottingham

August 4th to 6th, 53 participants

Will be held in LBNL on March 30 to April 1, 2015

Summary

- OB has **great influence** on building energy usage and also technology evaluation
- There are still lack of **quantitative methods, scientific criteria and common language** for OB description and simulation
- ANNEX 66 is focused on setting up **a scientific framework** for OB definition, description, simulation and applications in the coming four years efforts
- We are looking forward to cooperation and working with the teams all over the world to devote into Occupant Behavior Simulation research

Thank you for your attention!

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