A Framework to Describe Energy-Related Occupant Behavior in Buildings

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Simulation Research Group
Outline

• Research Background
• A Framework to Describe Occupant Behavior
• Relate to the Big Picture
  – U.S.-China CERC-BEE
  – IEA EBC Annex 66
Annual household electricity usage of split type air-conditioners in 2006, Beijing, China. Source: Tsinghua University

Research Background

Homestead Cohort:
Virtually identical Homes & Efficiencies...
... but 3x Variation in Energy Use
- Even greater differences at end-use level
- End-use data extremely valuable for forensic accuracy assessment

Source: Tsinghua University

Courtesy: 2008 NBI Study

Courtesy: Danny Parker, FSEC
Occupants Responses to Discomfort

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
Various Ways of Operating the Air-Conditioners

- always turn on
- turn on when entering
- turn on when feeling hot
- turn on before sleep
- never turn on
- randomly turn on
Occupant Behavior is one of the Key Elements to Achieving Low Energy Buildings
Significance of Research

• Technologies alone not necessarily guarantee low energy use in buildings

• Human behavior plays an essential role in building design, operation and maintenance, but it is not well understood and usually over-simplified or ignored!

• Behavior changes, usually no or low cost, has demonstrated 5 to 30% energy savings in buildings, but potential savings can be much more!
A Framework to Describe Occupant Behavior - the concept...

Energy-Related Occupant Behavior

- Drivers
- Needs
- Actions
- Systems
Drivers represent the stimulating factors that provoke energy-related occupant behavior.
Needs represent the requirements of an occupant that must be met in order to ensure satisfaction with the environment.
**Actions** are interactions with building systems or activities that an occupant can conduct in order to satisfy their **needs**
**Systems** are the equipment or mechanisms with which an occupant may interact to restore comfort.

![Diagram of systems](image-url)
The DNAS Framework

Energy-Related Occupant Behavior

Building

Drivers → Needs → Actions → Systems

Groups

Occupant

Climate & Weather

Report discomfort

Movement

Building Performance and Occupant Comfort
Example 1 – Window opening

Driver: Indoor air temp
Need: Thermal comfort
Action: Open
System: Window
Example 2 – Light operation

Driver: Work plane illuminance

Need: Visual comfort

Action: Switch on

System: Lights
The XML Schema - *obXML*
Applications of the Framework

• Building energy modeling
  ▪ Improve evaluation of building technologies and designs
  ▪ Better predict actual energy use in buildings

• Energy policy
  ▪ Energy benchmarking and performance rating
  ▪ Codes and standards
  ▪ Incentive programs

• Long term can be part of BIM
The U.S.-China Clean Energy Research Center for Building Energy Efficiency: Phase 2 Research Projects

EXECUTIVE COMMITTEE ON CERC-BEE (MoHURD and U.S. DOE)

Center for Building Energy Efficiency (MoHURD) and LBNL

- F Market Promotion
  - F1 Operation & Management
  - F2 TBA

- A Integrated Design & Operation
  - A1 Integrated Design
  - A2 Human Behavior
  - A3 TBA

- B Building Envelope
  - B1 Shading Systems
  - B2 Air Sealing
  - B3 Roofing Technology
  - B4 Hybrid Ventilation

- C Building Equipment
  - C1 Dehumidifier
  - C2 Lighting Controls
  - C3 Evaporative Cooling

- D Renewable Energy
  - D1 BIPV + Micro-grid
  - D2 GSHP

- E Construction
  - E1 Energy Systems
  - E2 Cx, Operation, and Evaluation
  - E3 Market Research

Pilot
New IEA EBC Annex 66:

Definition and Simulation of Occupant Behavior in Buildings

Operating Agents:
Da Yan, Tsinghua University, China
Tianzhen Hong, LBNL, USA
Five Technical Subtasks

Subtask A
Occupant movement and presence

Subtask B
Action Models in residential buildings

Subtask C
Action Models in commercial buildings

Subtask D
Integration of OB framework and models with simulation tools

Subtask E
Case Studies and Behavioral Guide

Fundamental Research

Practical Applications
<table>
<thead>
<tr>
<th>Subtask</th>
<th>Outcomes</th>
<th>Target Audience</th>
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<tr>
<td>B</td>
<td>Systematic measurement approach, simulation modelling and validation methodology</td>
<td></td>
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<tr>
<td>C</td>
<td>Occupant Behavior Database with data of different temporal and spatial resolutions</td>
<td></td>
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<tr>
<td>D</td>
<td>Software to simulate OB, integrated with a building thermal and energy model</td>
<td>Building Designers, Energy Saving Evaluators, HVAC Engineers, System Operators, Energy Policy Makers</td>
</tr>
<tr>
<td>E</td>
<td>Case studies and guidelines to demonstrate applications of the new OB definitions and models</td>
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</tbody>
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Participants from 24 Countries and Regions
• Preparation phase
  – One year (2013.11 — 2014.11)

• Working phase
  – Two years (2014.11 — 2016.11)

• Reporting phase
  – One year (2016.11 — 2017.11)
Questions?
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