Occupant Behavior Modeling Tools

A Public Webinar

Lawrence Berkeley National Laboratory
U.S. Department of Energy

10:30am – 12:00pm, PDT

March 15, 2016

Lawrence Berkeley National Laboratory

ENERGY.GOV

1. Building Technologies Office: R&D Directions & Opportunities, 5 minutes
   Karma Sawyer, Technology Manager, USDOE
2. Overview of U.S.-China CERC-BEE Consortium, 10 minutes
   Jimmy Tran, Operations Manager of CERC-BEE, LBNL
3. Introduction of occupant behavior modeling tools, 60 minutes
   Tianzhen Hong, PI, LBNL; Yixing Chen, Lead programmer, LBNL
4. Q & A, 15 minutes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building Technologies Office: R&D Directions & Opportunities

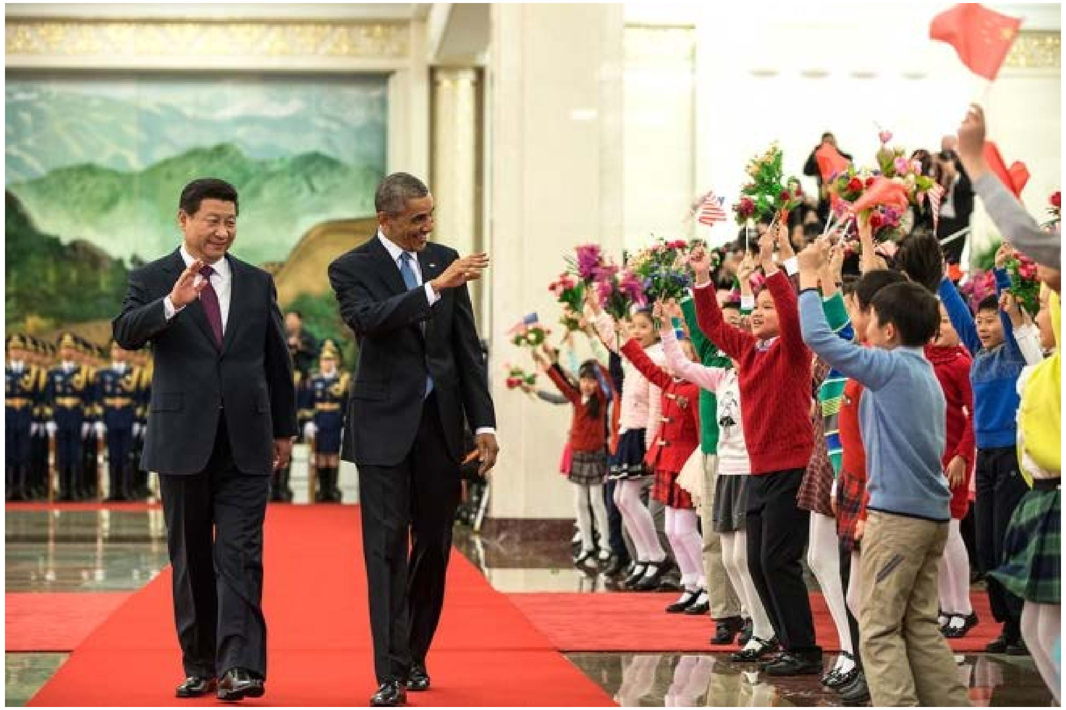
Karma Sawyer, Ph.D.
Technology Manager, CERC-BEE
March 15, 2016

U.S.-China Clean Energy Research Center (CERC)

CERC is a joint clean energy research & development program between the U.S. & China.

- **Established in 2009 by President Barack Obama & President Hu Jintao**
- **Renewed & expanded in 2014 for an additional 5 years (2016-2020)**

U.S. President Obama and China President Xi Jinping

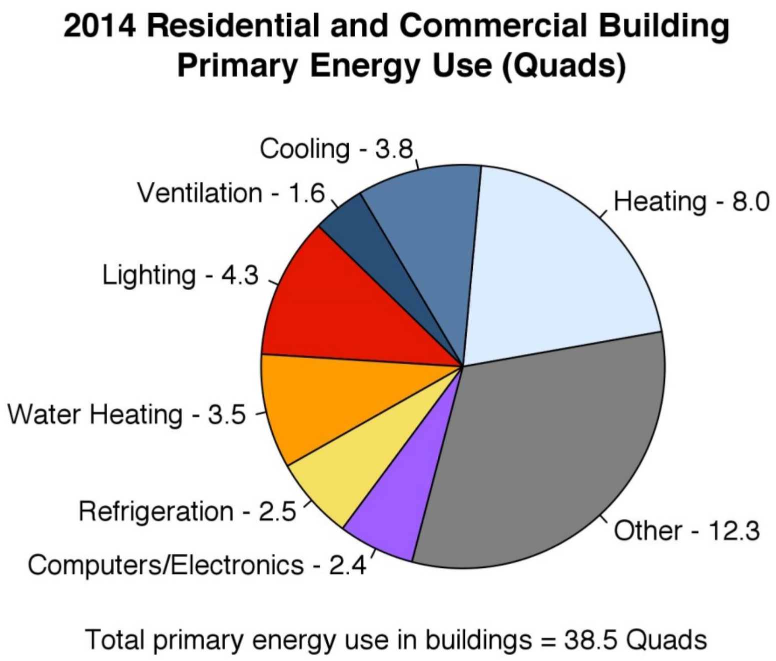


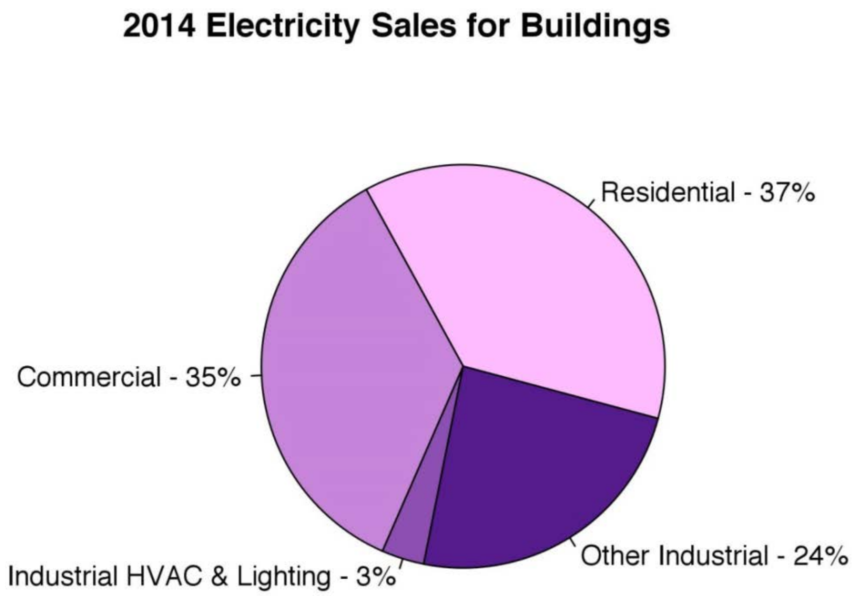
President Barack Obama and President Xi Jinping of China greet children during the State Arrival Welcome Ceremony at the Great Hall of the People in Beijing, China, Nov. 12, 2014

Five CERC Research Consortia

1. Advanced Coal Technology
2. Building Energy Efficiency
3. Clean Vehicles
4. Energy & Water
5. Medium & Heavy Duty Trucks

2014 Building Energy Use





Buildings use about 76% of the electricity, and about 40% of all primary energy, in the USA.

Sources: 2013, 2014 EIA Annual Energy Outlook; 2010 Manufacturing Energy Consumption Survey

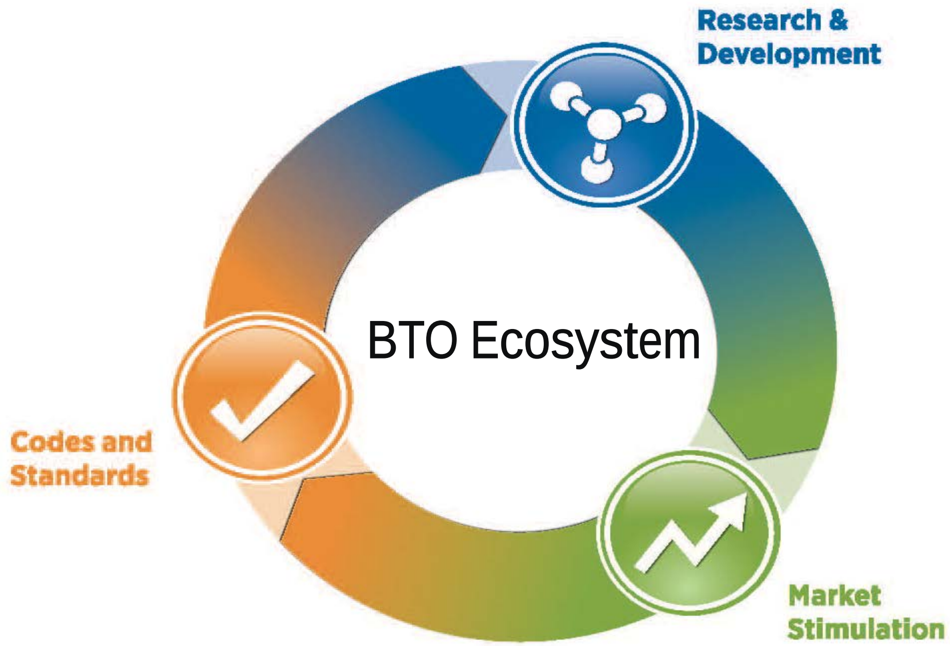
BTO’s Integrated Approach

Research & Development

- Develop technology roadmaps
- Prioritize opportunities
- Solicit and select innovative technology solutions
- Collaborate with researchers
- Solve technical barriers and test innovations to prove effectiveness
- Measure and validate energy savings

Market Stimulation

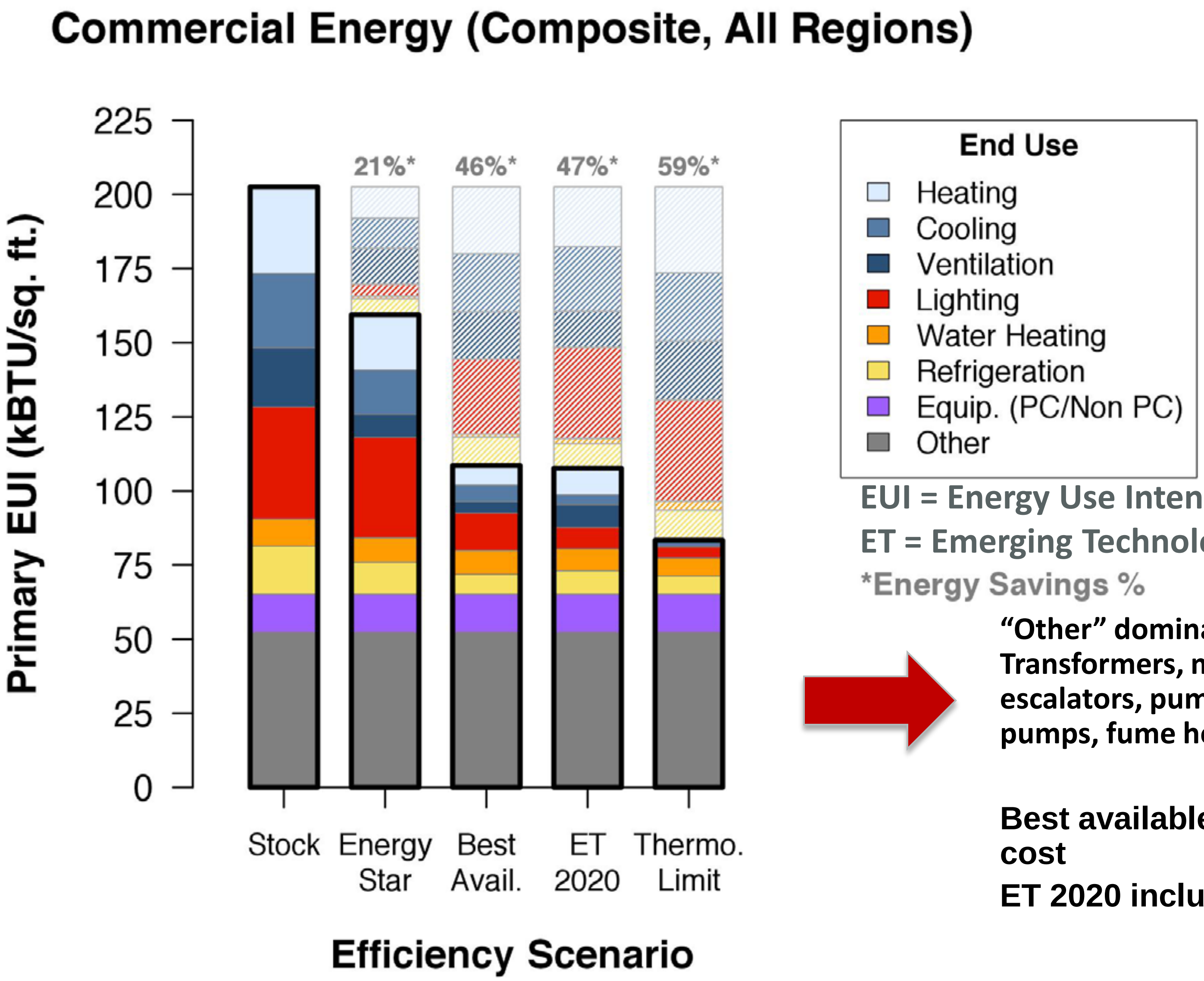
- Identify barriers to speed and scale adoption
- Collaborate with industry partners to improve market adoption
- Increase usage of products & services
- Work through policy, adoption, and financial barriers
- Communicate the importance and value of energy efficiency
- Provide technical assistance and training



Codes and Standards

- Establish minimum energy use in a transparent public process
- Protect consumer interests
- Reduce market confusion
- Enhance industry competitiveness & profitability
- Expand portfolio of EE appliances & equipment
- Raise the efficiency bar

Limits to Energy Efficiency (USA)



Source: *2015 DOE Quadrennial Technology Review, QTR* (Chioke Harris, Jared Langevin, Jack Mayernik, & Brent Nelson)

EUI = Energy Use Intensity

ET = Emerging Technologies

*Energy Savings %

"Other" dominates in future: Transformers, medical imagers, elevators, escalators, pumps, laundry equipment, pumps, fume hoods, CHP, etc.

Best available does not consider cost

ET 2020 includes cost effectiveness

Buildings R&D Opportunities in the QTR

Building thermal comfort and appliances	▪ Materials that facilitate deep retrofits (e.g., thin insulating materials) ▪ Low/no-GWP heat pump systems ▪ Improved tools for diagnosing heat flows over the lifetime of a building ▪ Clear metrics for the performance of building shells for heat and air flows
Lighting	▪ Test procedures for reliably determining the expected lifetime of commercial LED and OLED products ▪ Understanding why LED efficiency decreases at high power densities ▪ High efficiency green LEDs ▪ Efficient quantum dot materials ▪ Advanced sensors and controls for lighting ▪ Glazing with tunable optical properties ▪ Efficient, durable, low-cost OLEDs ▪ Lower cost retrofit solutions for lighting fixtures
Electronics and miscellaneous building energy loads	▪ More efficient circuitry (hardware and software) ▪ More flexible power management (hardware and software) ▪ Standardized communications protocols ▪ Wide-band-gap semiconductors for power supplies
Systems-level opportunities	▪ Accurate, reliable, low installed cost sensors ▪ Energy harvesting to power wireless sensors and controls ▪ Improved control systems (cybersecurity, install/commissioning) ▪ Control algorithms to automatically optimize building system performance ▪ Open-source software modules supporting interoperability ▪ Easy-to-use, fast, accurate software tools to design and operate buildings ▪ Co-simulation modeling with a widely used interface standard ▪ Decision science research incorporating personal information security ▪ Components and systems that allow building devices to share waste heat

Emerging Technologies: FY17 Emphasis

- Low GWP refrigerants
- Non vapor-compression refrigeration
- Grid modernization
- MELs (Miscellaneous Electric Loads)
- Decision science
- Envelope & windows
- Sensors & controls

Questions

- I will be available during the Q&A session at the end of the webinar.
- Or you can reach out directly: karma.sawyer@ee.doe.gov

Buildings Energy Efficiency Consortium

U.S. - CHINA CLEAN ENERGY RESEARCH CENTER (CERC-BEE)

Presentation for Webinar on Occupant Behavior Models

Jimmy Tran

Lawrence Berkeley National Laboratory

March 15th, 2016

Led by **MoHURD Center of Science and Technology of Construction** of China and **Lawrence Berkeley National Laboratory** of the United States with:

U.S. CERC-BEE ORGANIZATION

U.S. LEADERSHIP
DOE OPI
Bob Marley
U.S. Director, CERC

U.S. LEADERSHIP
DOE BTO
Roland Risser &
Karma Sawyer,
Technical Oversight

U.S. Advisors
Industrial Board
Clay Nesler
(Johnson Controls), *Chair*

Technical
Patrick Hughes
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John Millhone
Carl Blumstein

Strategic
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Tom McCawley
Brian Heimberg

LBNL
Nan Zhou
Director, CERC-BEE
Rick Diamond
Deputy Director, CERC-BEE
Jimmy Tran
Operations Manager
Yao Yuan
China Liaison

Research Groups

Industry

** Proposed

Impact and Approaches

100 million tons CO_2 reduction per year by 2025

Pioneering collaboration model with foundational IP protection

Accelerated technology development and deployment benefiting both countries

Development → **Demonstration** → **Deployment**

Technology Innovation:

- New state-of-the art products
- Software
- Tools
- Guidebooks

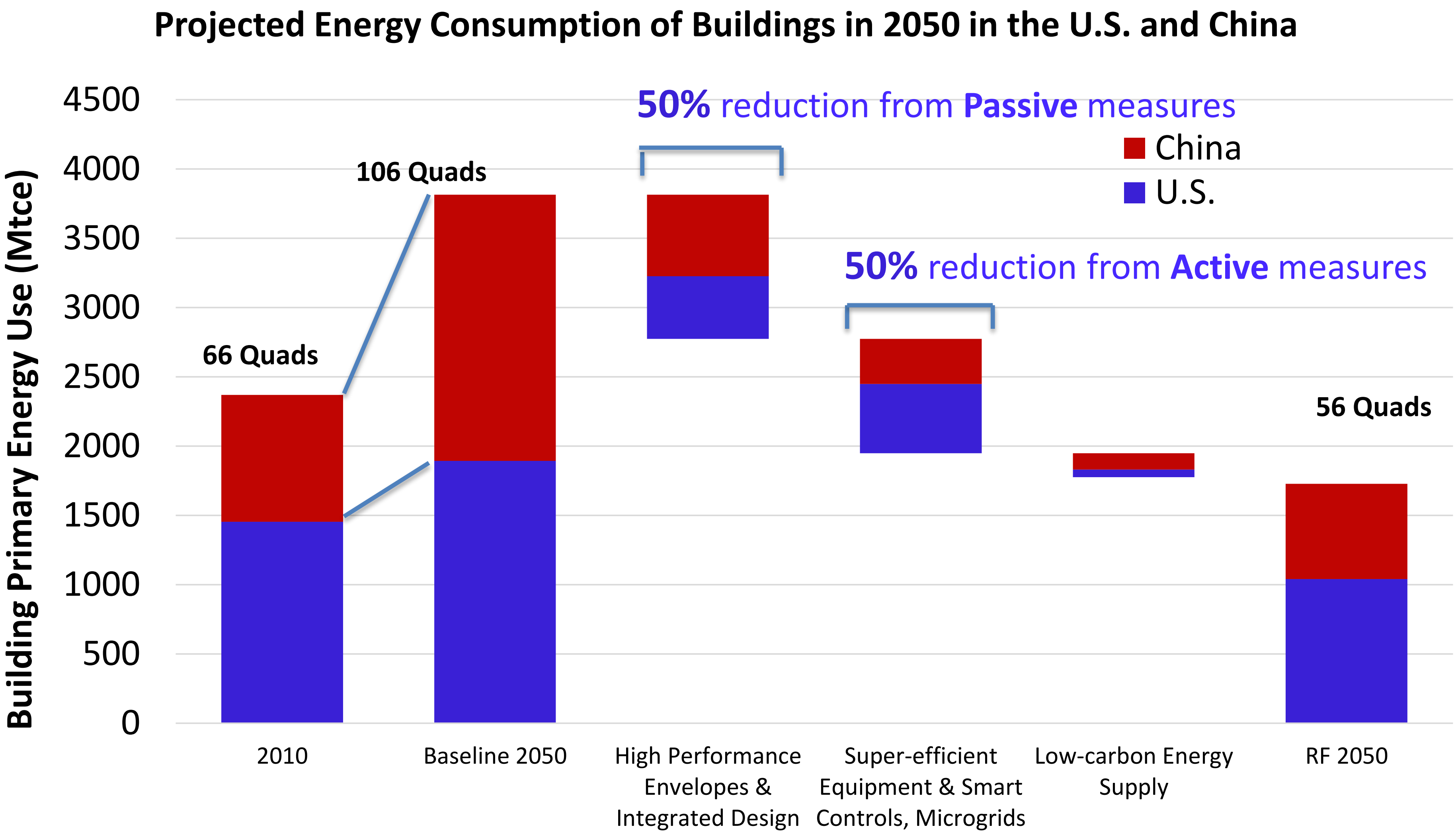
Pilot Buildings:

- Demonstrating value of technologies
- Accelerating development
- Commercial impact

Codes and Market:

- Industry commercialization
- Policies and standards
- Trainings
- Developers as path to market

50% Reduction Potential in buildings in both U.S. and China



Note: U.S. numbers *based* on RMI Reinventing Fire, China numbers based on LBNL 2050 DREAM model

Benefits to Both Countries

1. **Accelerated technology development** through access to world-class scientists
2. **Real world impact** through commercialization
3. **New technologies with robust applications in the global market** developed for energy-efficient buildings
4. **Expanded markets** for U.S. technologies valued at ~ $50B/year
5. **Cost-effective and scalable** solutions reduced energy use in buildings and CO_2 emissions
6. **Increased demand** for deployment of energy efficient building technologies through successful demonstrations and by policies and codes
7. **Insights from new data** facilitated through the bi-lateral CERC R&D model
8. **Protected intellectual property** of U.S. industrial partners through a pioneering, enhanced U.S. - China agreement
9. **Model collaborative R&D program** providing opportunities for expanded international cooperation on energy efficient buildings and more
10. **Long-term partnerships with demonstrated results** linking governments, universities, research institutions including U.S. national laboratories, and industry

Unique Business Benefits in the U.S. and China Compared to Traditional Bi-lateral R&D Programs

Access and Input

- Inform new policies/initiatives, stimulating the penetration/adoption of energy efficient technologies and practices
- Direct access to governments, official policy making institutions, U.S. national laboratories, and Chinese research, policy institutes, and companies
- Recognition as a Member at major conferences and workshops

Market Development and Special IP Protections

- Better understanding of, and access to expose new technologies to large markets
- Enhanced IP protection and assistance in China side licensing agreements

>71 Research & Industry Partners

Supported by U.S. Department of Energy and China Ministry of Science Technology, with:

>13 U.S. & China Research Partners

MoHURD Center of Science & Technology of Construction

Tsinghua University

China Academy of Building Research

Chongqing University

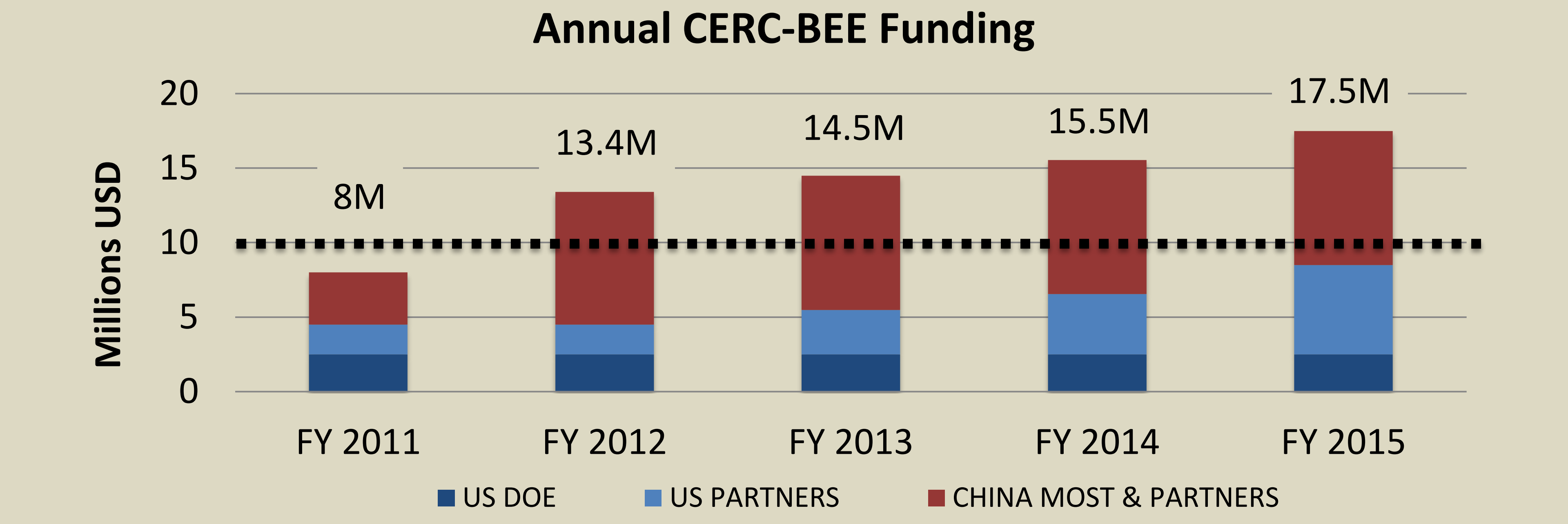
Tongji University

Tianjin University

China Society for Urban Studies

>59 U.S. & China Industry Partners including:

Industry engagement strongest ever



- Industrial partners see value, demonstrated by +30% annual average growth rate for cash and in-kind contributions to date
- Initial 5-year total program funding of $69M vs. $50M planned (+38%)
- Presidents Obama & Xi renewed CERC for another 5-yrs 2016-2020
- Expanded industry engagement through affiliates programs

List of Key Accomplishments

Products Launched
- 3M: 3M 3015 product launch of primerless self-adhering membrane
- ClimateMaster: Co-axial ground heat exchanger (GHX) and Trilogy integrated heat pump
- DOW: LIQUIDARMOR – RS and LIQUIDARMOR – CM

Patents & Invention Disclosures
- DOW Air sealing - US 8,641,846 B2
- Smart Pumping Control for Hydraulic Distribution Systems
- Incorporation of SH powders in water based acrylic coatings
- LBNL's "Cool Roof Time Machine" (ASTM D7897-15) cuts prototype testing to **3 days** from 3 years

Standards, Codes, Policies
- ISO 15099 for standardized characterization of window and fenestration products
- China Building Energy Consumption Standard
- MOHURD national energy performance benchmarking and disclosure (EPB&PD) policy

Copyrights Software
- Enhancement to EnergyPlus, Behavior software module
- DER-CAM, webopt and operation DER-CAM
- Online Hotel Commercial building benchmarking tool for China

Demonstration projects yield meaningful technological progress

CERC-BEE 2.0 Unique Approaches

CERC-BEE 1.0	CERC-BEE 2.0
Technology silo	System efficiency
Independent projects	Integrative programs encouraging cross area collaboration
Independent IP	Potential for Joint IP
Many small projects & incremental improvements	Fewer, yet high impact & prominent technology breakthroughs
No developers	Adding large scale developers and builders, engage more Chinese industry partners
individual buildings	Expanding to building complex and communities
Disconnect policy and deployment research	Market and Policy research support each project
Academia led projects	More IAB partner led projects to ensure commercialization

Integrated Design, Construction and Industrialized Building

Problem: Façade energy-saving features are limited by: poor construction site workmanship and/or the difficulty enforcing, through construction site inspections, stringent passive envelope energy codes.

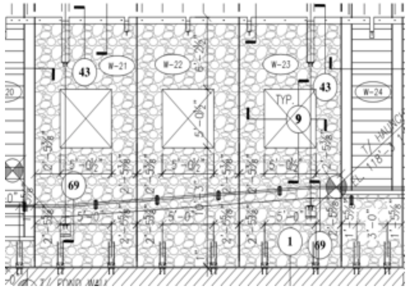
Impact: Facade integrated design and prefab construction: provides a platform for optimal integration of energy saving features into facades for new construction or existing building re-skins.

Energy saving features that can be integrated:
(1) insulation, (2) air sealing, (3) high albedo exterior surfaces, (4) exterior shading of fenestration, (5) harvesting of daylight and passive solar heating, (6) provisions for natural ventilation, and (7) lower embodied energy and environmental impact materials.

Industrialized building advances:
(1) design standardization, (2) factory production, (3) construction site assembly , (4) architectural feature integration, (5) materials waste reduction, and (6) building information modeling (BIM) for improved cost and QA/QC management.

4. New/Retrofit Finished Facade

1. Integrated Precast Façade Design



3. Pour/Ship/Assemble Modules

2. New: 3-D Printed Precast Forms

2. Old: Handcrafted Precast Forms

Integrated Sensors, Controls and Commissioning

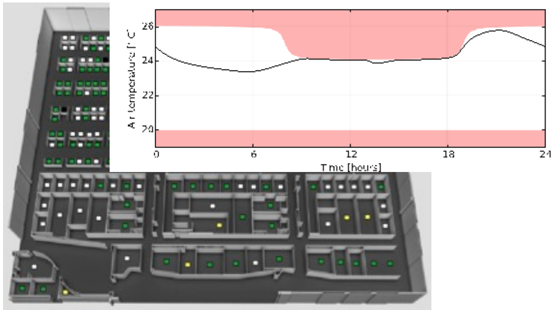
Problem
- Building operation needs to become elastic, energy-optimized, grid-aware and occupancy responsive

Approach
- Develop and demonstrate open-source, Hierarchical Occupancy Responsive Model Predictive Control at Room, Building and Campus Levels, built on open standards, consisting of
  - machine learning for user behavior, occupancy and load prediction, and for model and state identification to reduce commissioning time, adjust to actual operation, and provide information about performance degradation for continuous commissioning, feeding into
  - Hierarchical Model Predictive Controllers that dynamically control rooms, buildings and campus, and
  - dashboards that inform occupants, building operators and campus managers about how to save energy or shed loads, and that retrieve their comfort and operation preferences

Outcome
- Building and district energy systems that optimize their operation across end-uses, learn about the energy system dynamics and user's comfort preferences and inform the building occupants and operator about how to reduce energy consumption
- On site demonstration within an open infrastructure that allows start-up to also test and integrate their technologies

Machine learning
for system identification

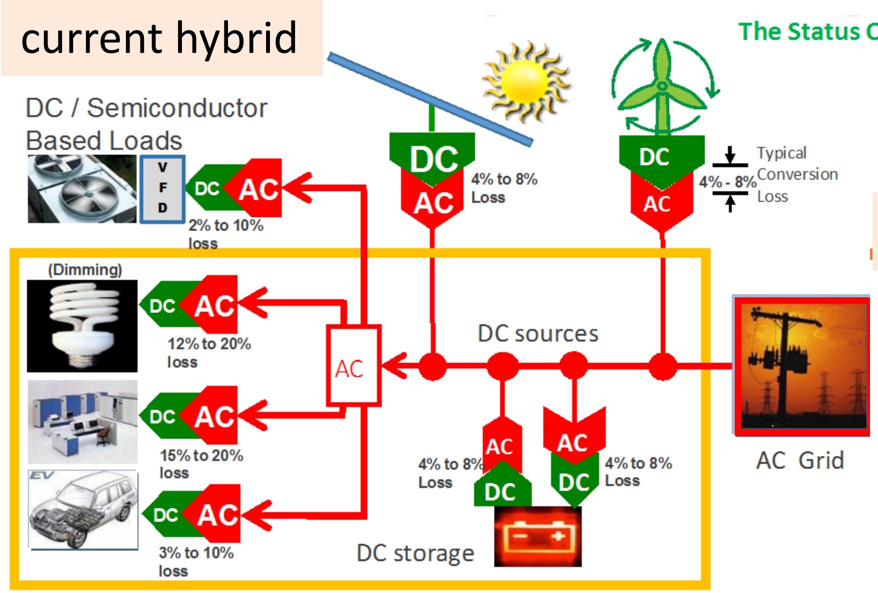
Energy/Comfort
Dashboards



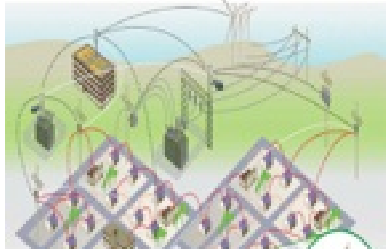
Occupancy-responsive Model
Predictive Control

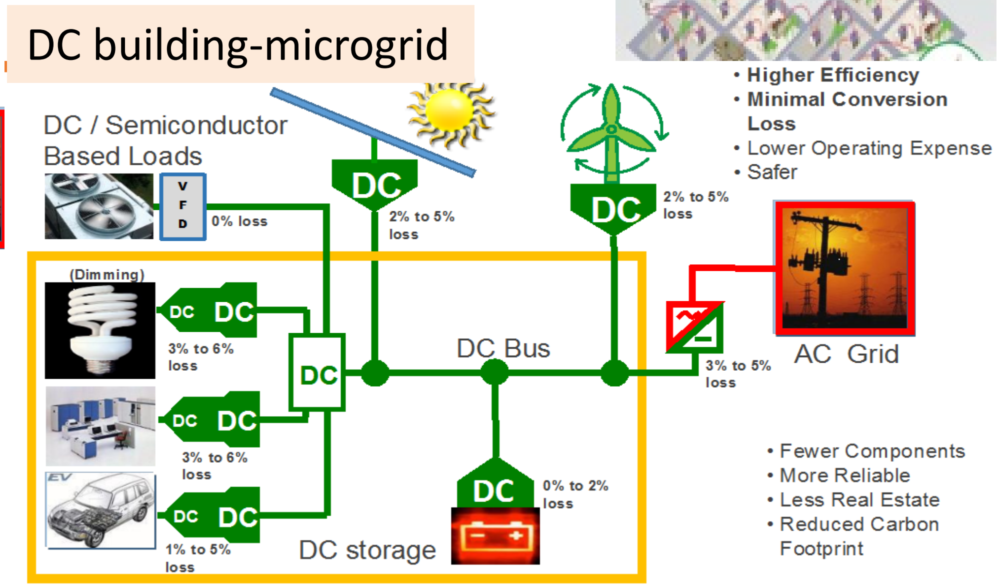
Hierarchical distributed, occupancy-
and grid-aware operation

DC Buildings and Smart Grid



source: Emerge Alliance





- Current hybrid buildings with on-site generation-storage require many energy conversions.
- Current commercial buildings have about 1/3 efficient loads involving DC, i.e. electronics, lighting, variable speed motors, etc. and the fraction is growing.
- Eliminating conversions DC → AC → DC saves 10-20% electricity consumption.
- DC has other power quality advantages, so future buildings may use both.
- China conditions amenable to development of DC building systems

Indoor Environment Quality

PROBLEM: Outdoor air ventilation for commercial buildings limits energy and CO_2 savings opportunities and impacts indoor air quality because*:*

– The outdoor air must be thermally conditioned
– The most conditioning energy is often needed during peak times
– Outdoor air pollutants (e.g., particulate matter) increase indoors

GOAL: Develop and demonstrate technologies that manipulate air supply for energy-efficient HVAC while providing excellent indoor environmental quality.

APPROACH: Advances will be made in the following areas:

– Develop and demonstrate air cleaning technologies for fine particulate matter ($PM_{2.5}$), ozone, formaldehyde, volatile organic compounds (VOCs) and carbon dioxide (CO_2).
– Integrate air cleaning with ventilation by real-time monitoring using low-cost sensors
– Develop simulation tools to aid system design & selection for different building types, climates and air quality challenges

Enhanced removal of indoor and outdoor contaminants

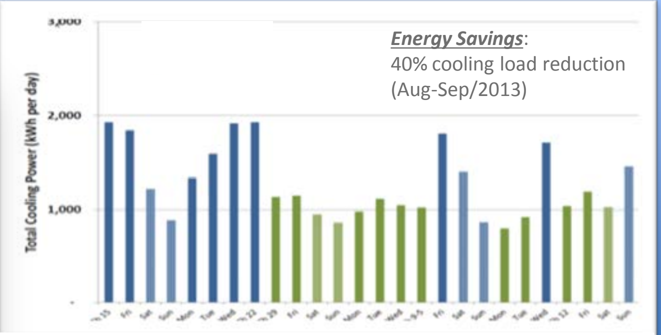
Reduced need for outdoor air ventilation

Lower HVAC energy costs & excellent indoor air quality

ACTIVITIES: Joint US-China teams will develop novel air cleaning materials, demonstrate air cleaning systems and sensing networks in Chinese buildings, and develop and apply simulation and other evaluation tools.

CASE STUDY: Office building in San Antonio, Texas

Images provided by Enverid



Green: air cleaning ON; Blue: air cleaning OFF

Example Technology: Enverid HLR system with BASF sorbent materials that remove CO_2 and VOCs.

- increases HVAC energy efficiency
- provides and monitored continuously good indoor air quality, reducing intake of outdoor pollutants
- Significant impact on peak electricity demand with reduced GHG emissions

Policy & Markets Initiative

Objective: Accelerate the market penetration of advanced CERC technologies during new construction, major retrofit, and minor retrofit in the United States and China through the following solutions:

CERC 2.0 Solution	Background/Description	Goals	Opportunity Areas		Annual Savings	
			New Construction Major Retrofit	Minor Retrofit	United States	China
Systems Dynamic Model	Current DOE technology/policy impact assessment tools focus only on the US. We will expand the system dynamics model developed for CERC 1.0 to evaluate the impact of variations to market and policy solutions in <u>both the US and China</u>, in order to inform decision-making, and ultimately our policy implementation recommendations	By 2020, inform the development of outcome-based code, retrofit, and finance policies; impact and scale up potential of these policies; as well as price points for the adoption of CERC 2.0 technologies	✓	✓	**Energy Use: 3.9 Quads Emissions: 375 MtCO2**	**Energy Use: 5.3 Quads Emissions: 500 MtCO2**
Outcome-Based Code Models	Traditional codes fall short in being able to drive the implementation of very low energy buildings; we will help drive the development of an outcome based code that can capture <u>all the savings</u>, <u>verified</u>	By 2020, China's national 14th 5-year plan (2020–2025) specifies the development and DOE provides guidance to cities for developing outcome based codes for very low energy buildings	✓			
Retrofit Models	Current retrofit implementation models have not been able to achieve the scale required of them; we will work with implementation partners to <u>pilot and scale new retrofit and financing models</u>	By 2020, deliver working retrofit and financing models that are in the process of scaling in one China city and one US city		✓		

Contact Jimmy Tran jtran2@lbl.gov for further information

Occupant Behavior Modeling Tools

- Introduction
  - A CERC-BEE 1.0 project (2013 – March 2016)
- Three occupant behavior modeling tools
  1. Occupancy Simulator, a web App for simulating occupant presence and movement in buildings
  2. obXML, an XML schema for representation and exchange of occupant behavior models
  3. obFMU, a functional mock-up unit (FMU) of occupant behavior models for co-simulation
- Next steps
- Resources

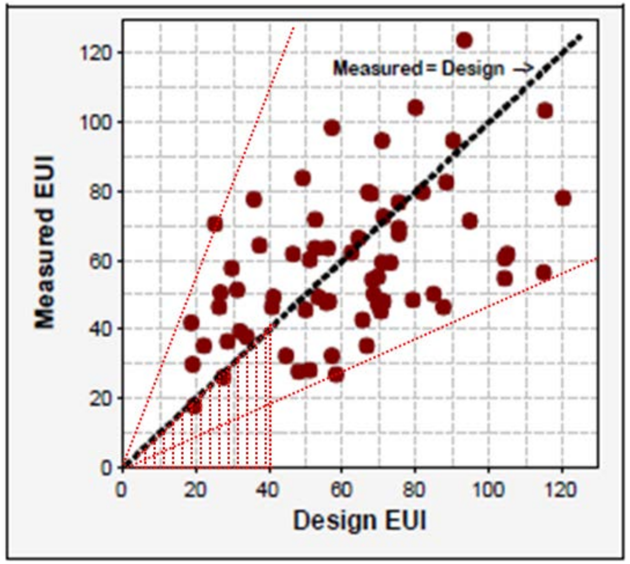
behavior.lbl.gov

occupancysimulator.lbl.gov

www.annex66.org

Introduction

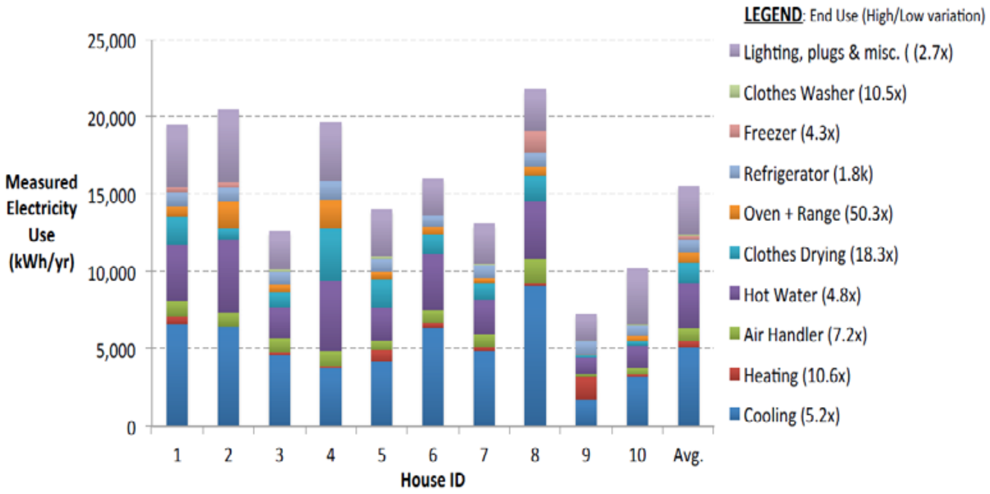
- Why behavior research?
  - Technologies alone not necessarily guarantee low energy use in buildings.
  - Human behavior plays an essential role in buildings, but it is not well understood and usually over-simplified.
  - Behavior changes, usually no- or low-cost, has demonstrated 5 to 30% energy savings in buildings, but potential savings can be more in very low energy buildings.
- Occupant behavior is complex
  - Stochastic in time and space
  - Diversity
  - Multidisciplinary
  - Sensing and data is a challenge



2008 NBI Study of LEED NC certified buildings

Energy-related occupant behavior in buildings, e.g.:

- Open/close windows
- Switch/dim lights
- Adjust thermostat
- Movement
- Turn on/off HVAC
- Operate shades
- Adjust clothing
- Turn on/off plug-loads



Courtesy: Danny Parker, FSEC

Impact of occupants:

- Passive effect: heat and moisture gains from occupants
- Active effect: occupants interact with lighting, plug loads, HVAC, windows and shades

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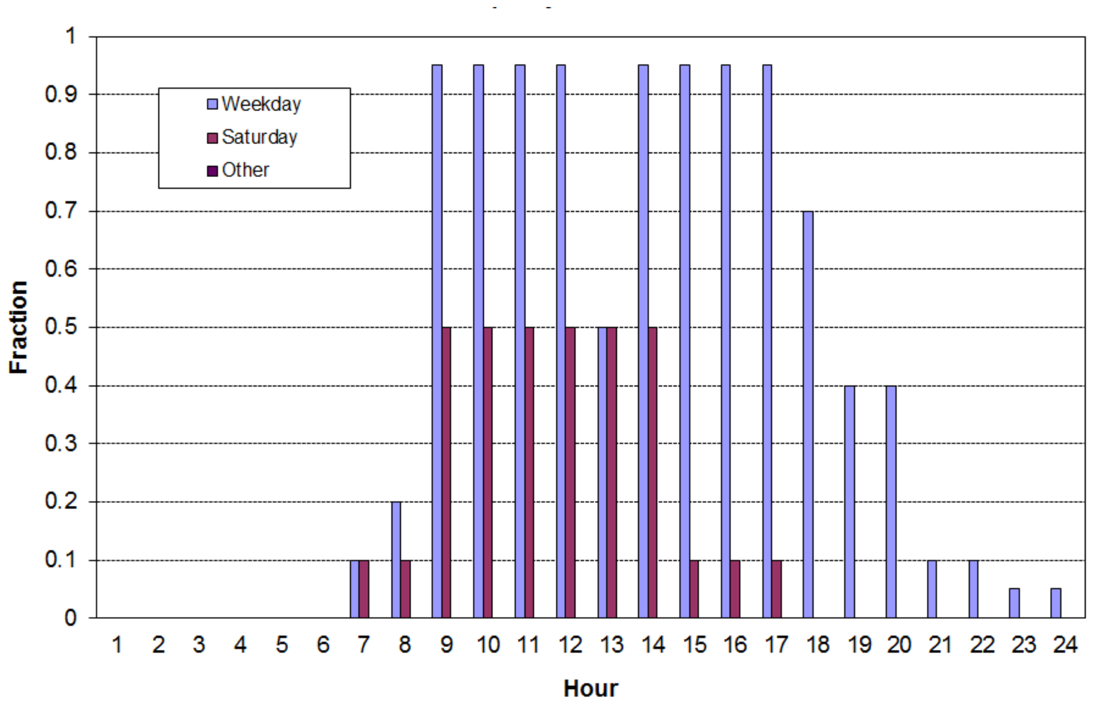
State-of-the-art

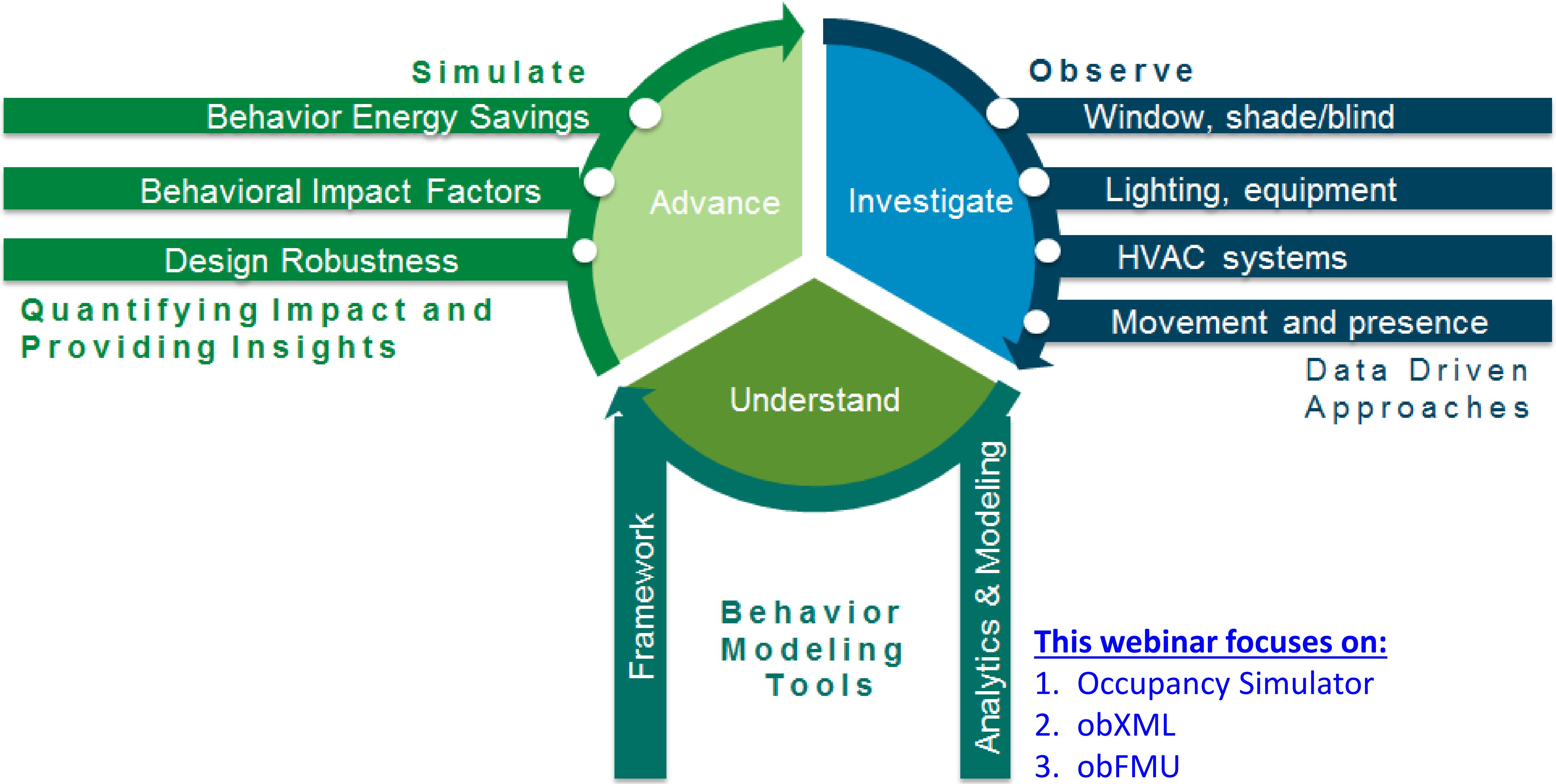
Limitations of occupant input in current building simulation programs:

- Use deterministic or static settings and rules
- Assume homogeneous profiles
  - Schedules, comfort requirements
- Hard to use custom features, e.g.
  - EnergyPlus EMS (Energy Management System)
  - DOE-2 User Function
  - IDA ICE NMF
- Simulation programs represent occupant input differently
  - No standardization
  - Cannot reuse models or data



Occupant schedules used in the DOE reference building models

Research Approach on Occupant Behavior in Buildings



This webinar focuses on:

1. Occupancy Simulator
2. obXML
3. obFMU

Occupancy Simulator

- Occupant schedule is crucial to building energy simulation
- Simplified occupant schedules lack diversity and stochastics

Occupancy Simulator:

- A web Application running on multiplatform and devices
- Uses Markov Chain model to simulate movement of each occupant
- A simple and layered way for user input
- Produces occupant schedules for spaces and individual occupant
- Downloadable schedules in csv and IDF files

Markov Chain model

- Determine the location of each occupant based on their previous location and a transition probability matrix

$$X(t) = i \xrightarrow{p_{ij}} X(t+1) = j$$

- Transition Probability Matrix

$P_{i,j}$: The probability of an occupant moving from location (i) to location (j)

$$P_{t,t+1} = \begin{bmatrix} P_{00} & P_{01} & \cdots & P_{0n} \\ P_{10} & P_{11} & \cdots & P_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n0} & P_{n1} & \cdots & P_{nn} \end{bmatrix}$$

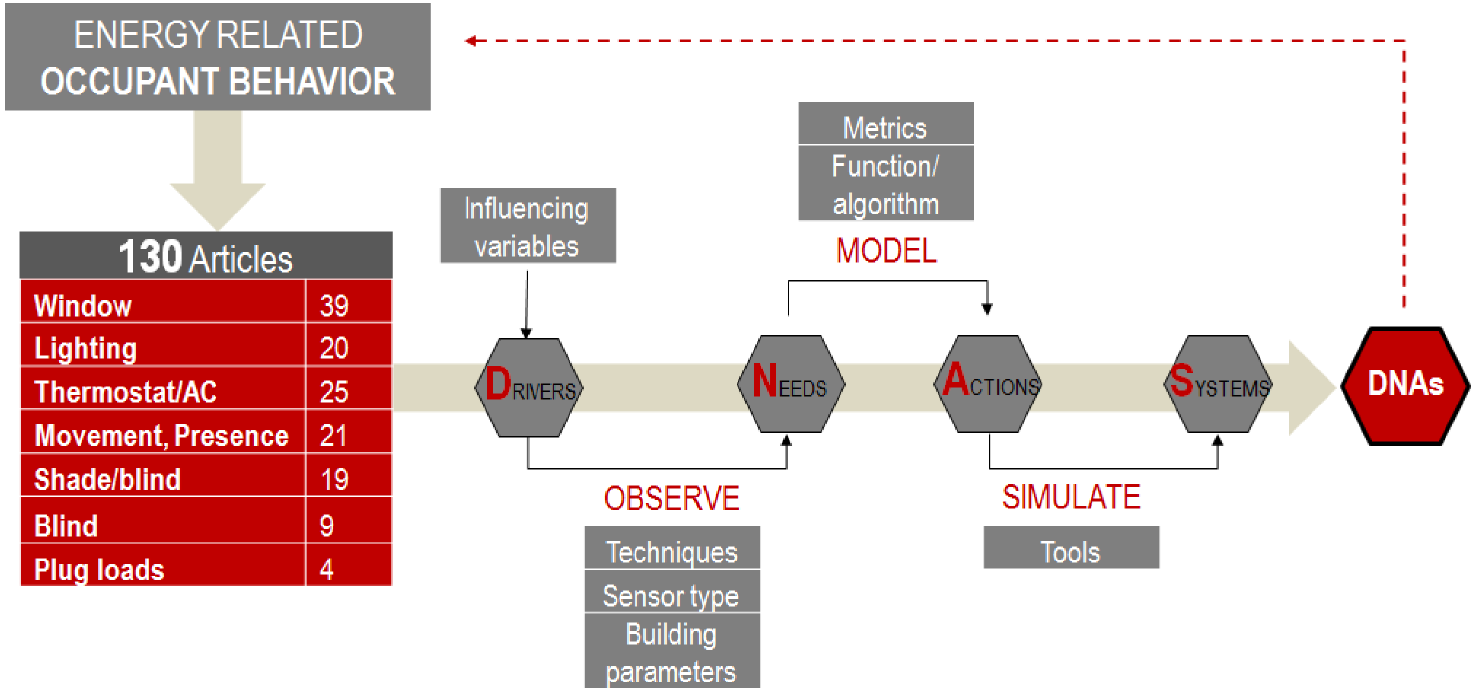
References:

1. C. Wang, D. Yan, Y. Jiang. A novel approach for building occupancy simulation. Building Simulation, 4(2): 149-167, 2011.
2. X. Feng, D. Yan, T. Hong. Simulation of occupancy in buildings. Energy and Buildings, 87: 348-359, 2015.
3. Y. Chen, X. Luo, T. Hong. An Agent-Based Occupancy Simulator for Building Performance Simulation, ASHRAE Annual Conference, 2016

Demonstration of the Occupancy Simulator

OccupancySimulator.lbl.gov

The DNAS Framework for representing occupant behavior in buildings



The DNAS Framework:

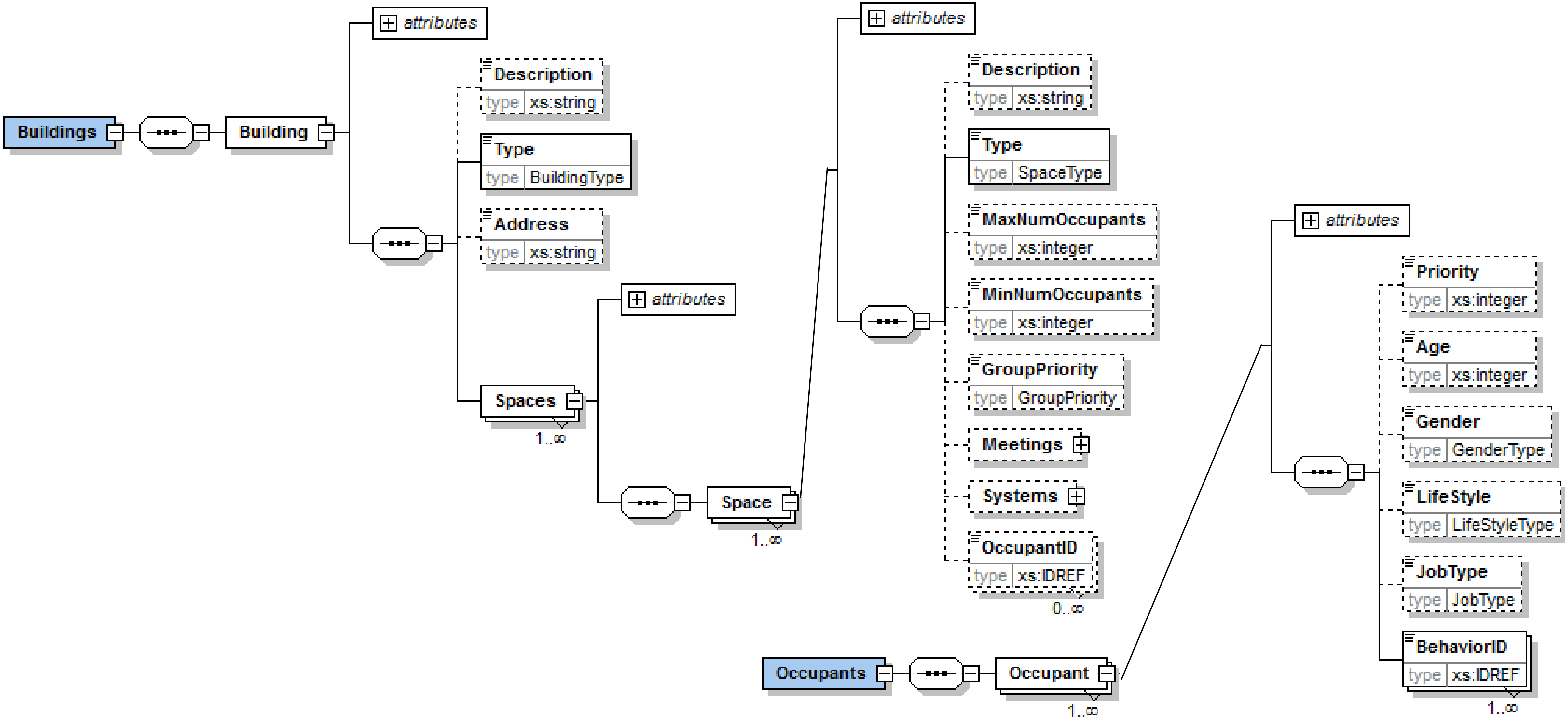
- *Drivers* represent the stimulating factors that provoke energy-related occupant behavior
- *Needs* represent the requirements of an occupant that must be met in order to ensure satisfaction with the environment
- *Actions* are interactions with building systems or activities that an occupant can conduct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

An example – opening a window

References:

1. 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
2. T. Hong, S. D'Oca, W. Turner, S.C. Taylor-Lange. An ontology to represent energy-related occupant behavior in buildings. Part I: Introduction to the DNAs Framework. Building and Environment, 2015

obXML – An XML schema implementing the DNAS framework



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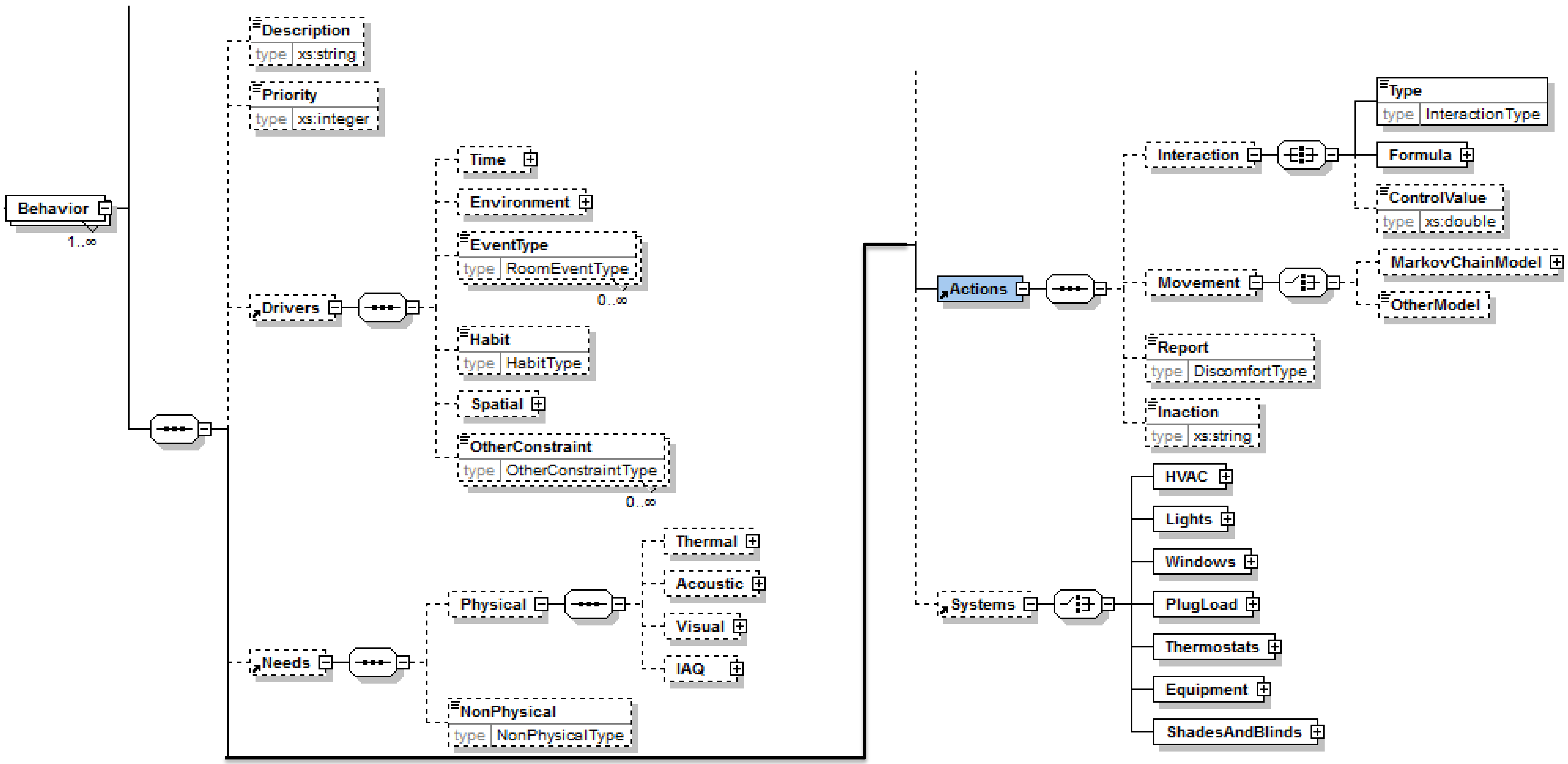
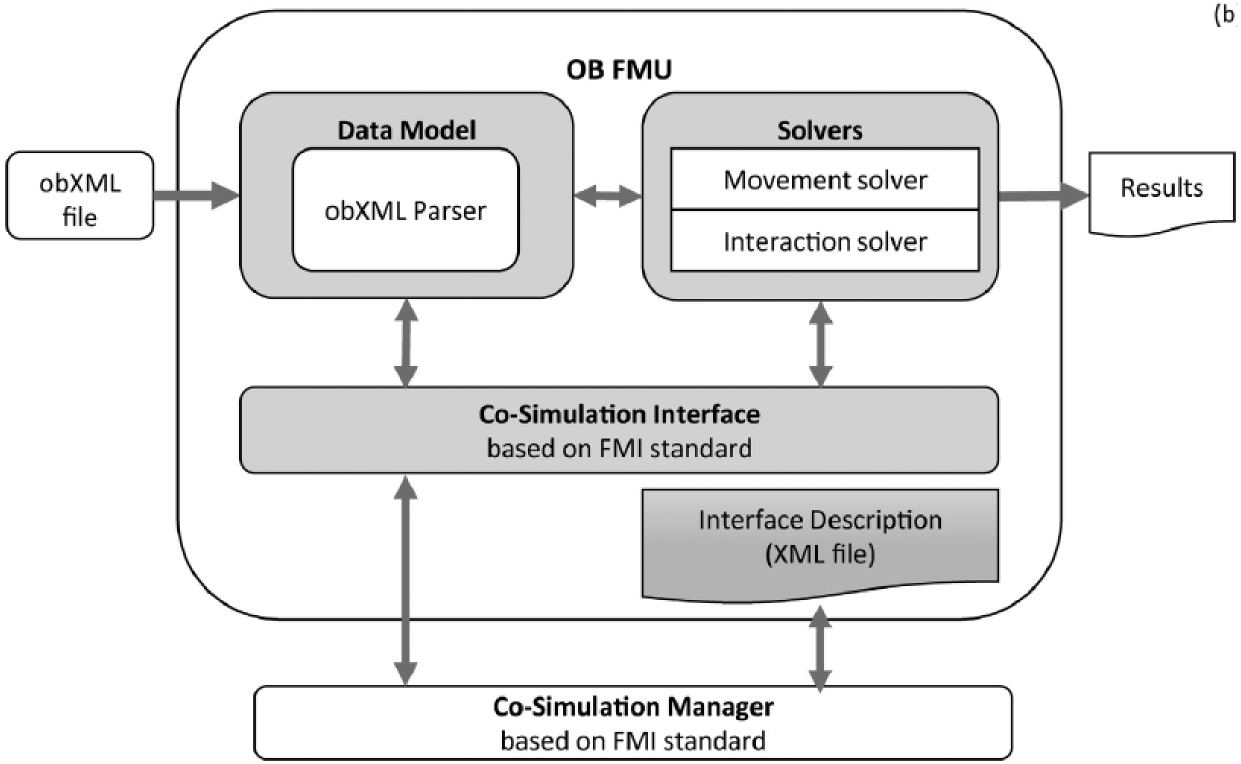
obXML Schema - Behavior



obFMU

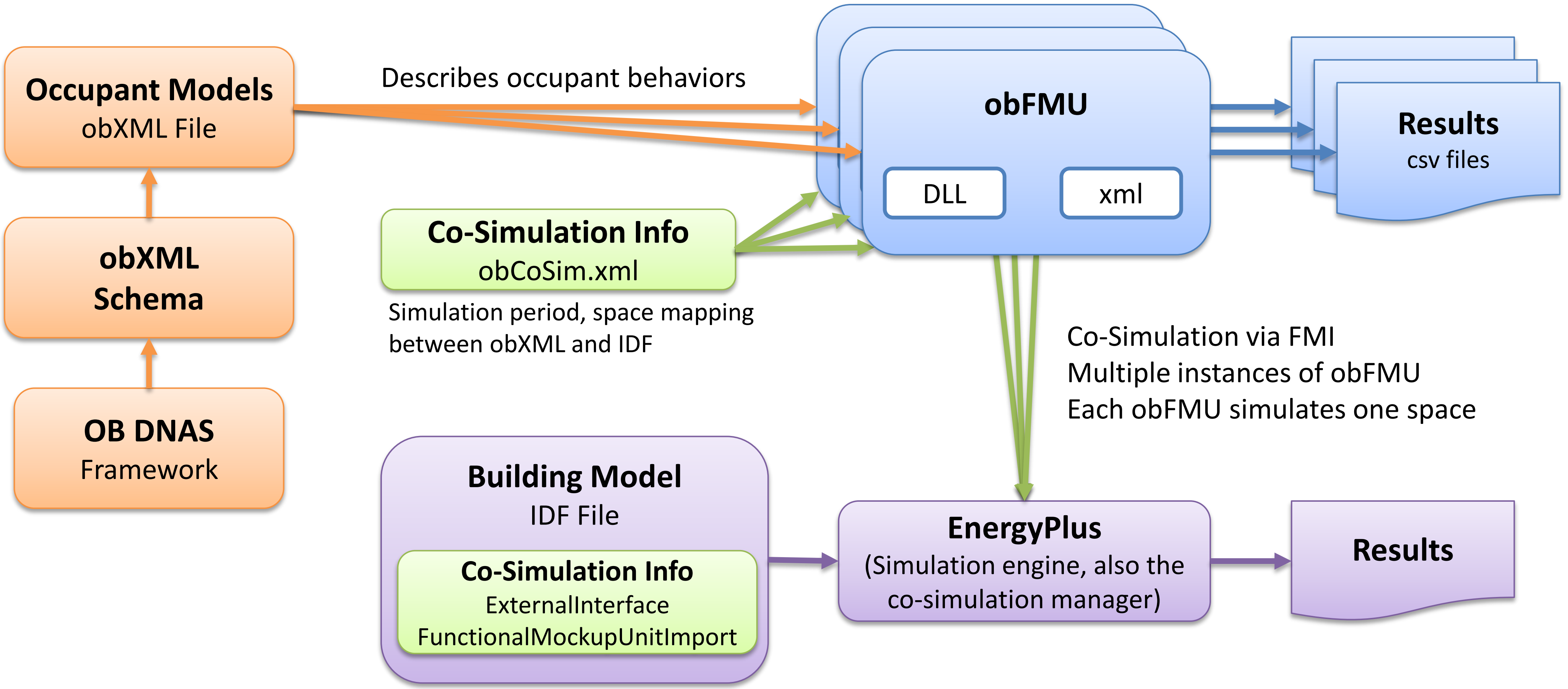
- A Functional Mock-up Unit (FMU) of occupant behavior models
- Support co-simulation with building simulation programs, e.g., EnergyPlus
- Implement occupant behavior models for:
  1. Controls: on, off, proportional
  2. Systems: windows, shade/blind, lights, plug loads, thermostat, and HVAC
  3. Events: entering, leaving, meeting, lunch
  4. Various probabilistic models



- Reference

  T. Hong, Y. Chen, S.C. Taylor-Lange, H. Sun, D. Yan. An occupant behavior modeling tool for co-simulation. Energy and Buildings, 2016

obFMU – Software Architecture



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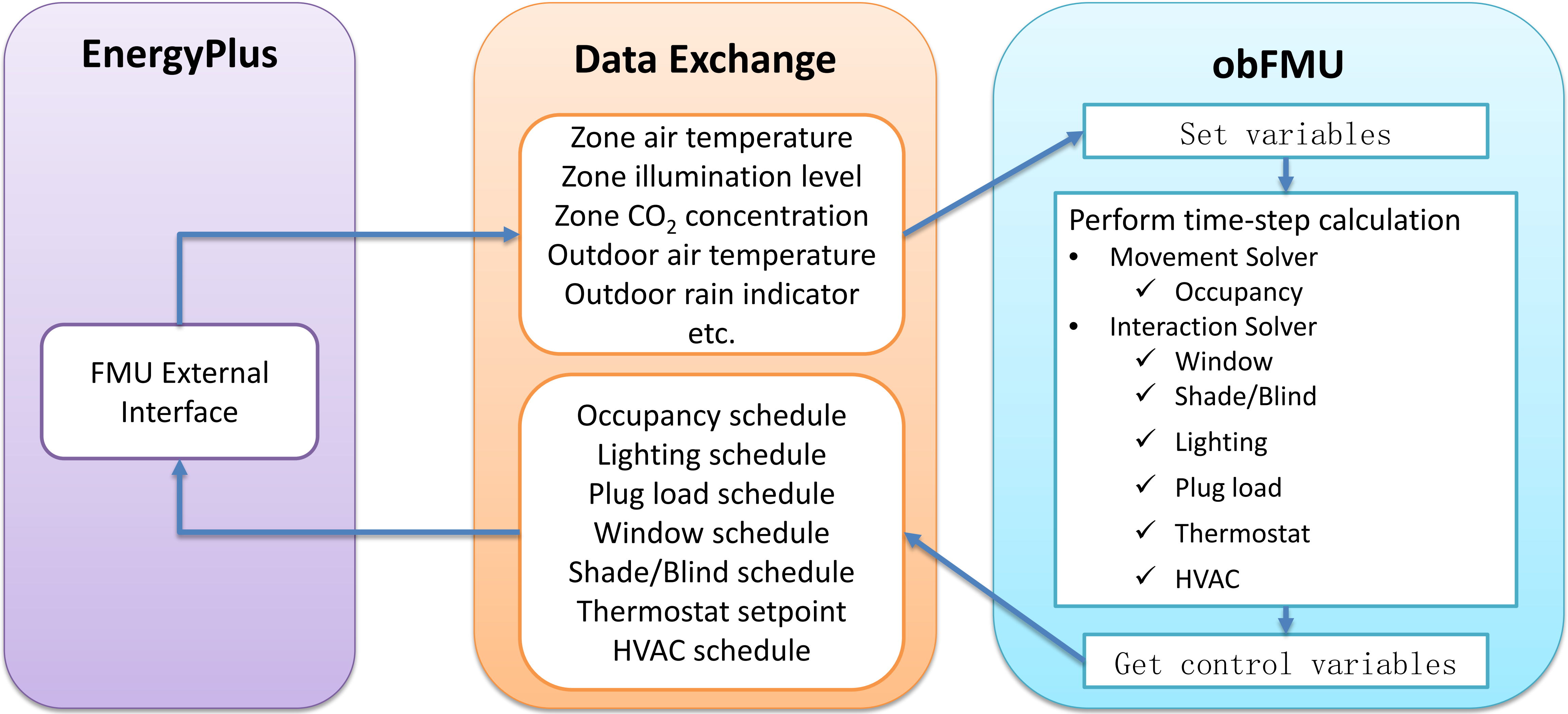
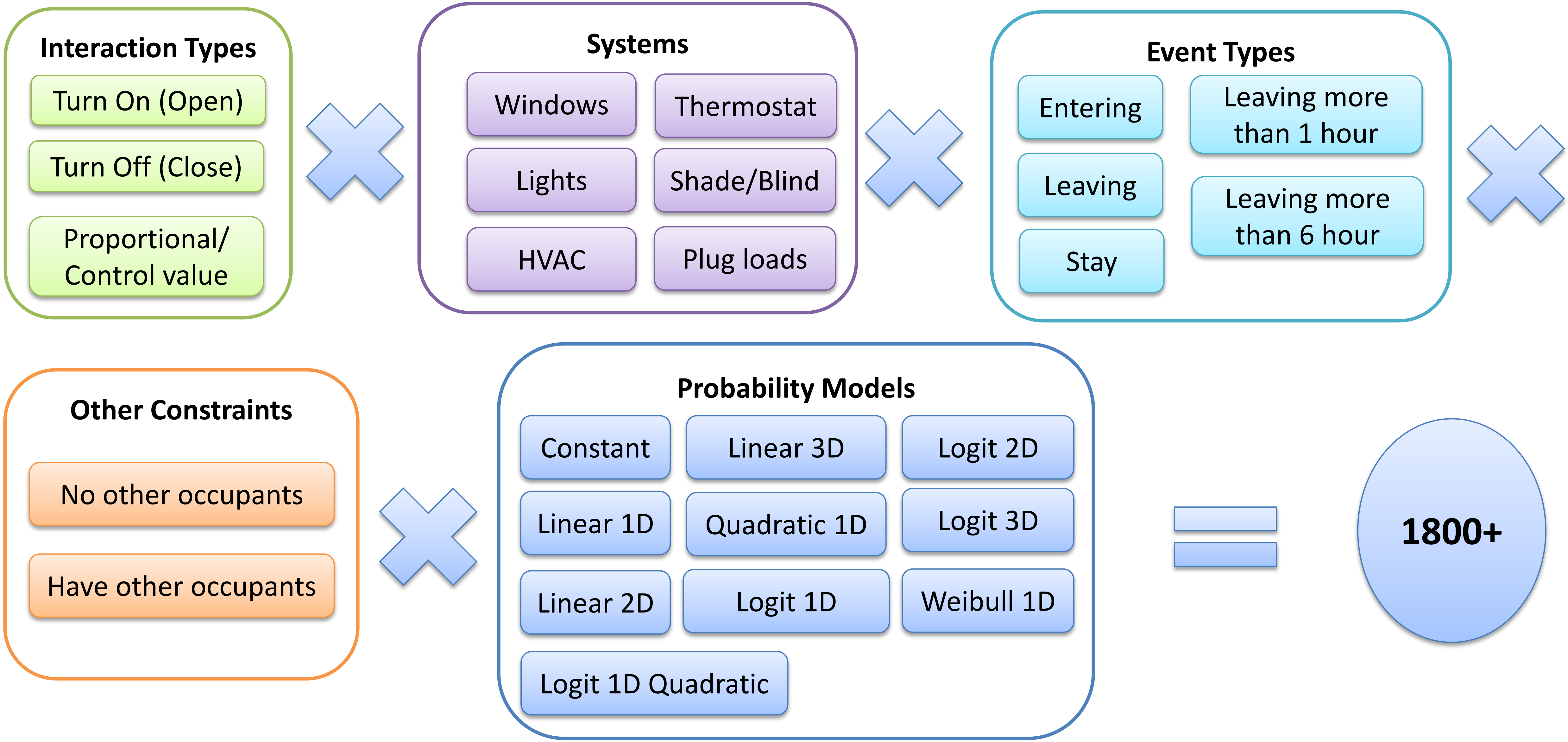
obFMU – Data Exchange and Work Flow



Types of Occupant Behavior Models Implemented in obXML and obFMU



An Example – Hunt's lighting use model (1980)

Turn on lights based on daylight illuminance using Logit 1D Quadratic Model.

Interaction Type	System	Probability Model
Turn On	Lights	Logit1D Quadratic

```xml
<Behavior ID="B_Light_Hunt_1980_Logit_1D_Quadratic">
  <Description>
    Hunt's lighting use model (1980)
  </Description>
  <Drivers>
    <Environment>
      <Parameter ID="P1" Name="Daylight illuminance">
        <Type>RoomWorkPlaneDaylightIlluminance</Type>
      </Parameter>
    </Environment>
  </Drivers>
  <Needs>
    <Physical>
      <Visual>
        <ParameterRange>
          <ParameterID>P1</ParameterID>
          <Min>658</Min>
        </ParameterRange>
      </Visual>
    </Physical>
  </Needs>
  <Actions>
    <Interaction>
      <Type>TurnOn</Type>
      <Formula>
        <Logit1DQuadratic>
          <Description>
            p = A + C / {1 + exp(-B*[log(P1)-D]}
          </Description>
          <CoefficientA>-0.0175</CoefficientA>
          <CoefficientB>-4.0835</CoefficientB>
          <CoefficientC>1.0361</CoefficientC>
          <CoefficientD>1.8223</CoefficientD>
          <Parameter1ID>P1</Parameter1ID>
        </Logit1DQuadratic>
      </Formula>
    </Interaction>
  </Actions>
  <Systems>
    <Lights>
      <LightType>OnOff</LightType>
    </Lights>
  </Systems>
</Behavior>
```

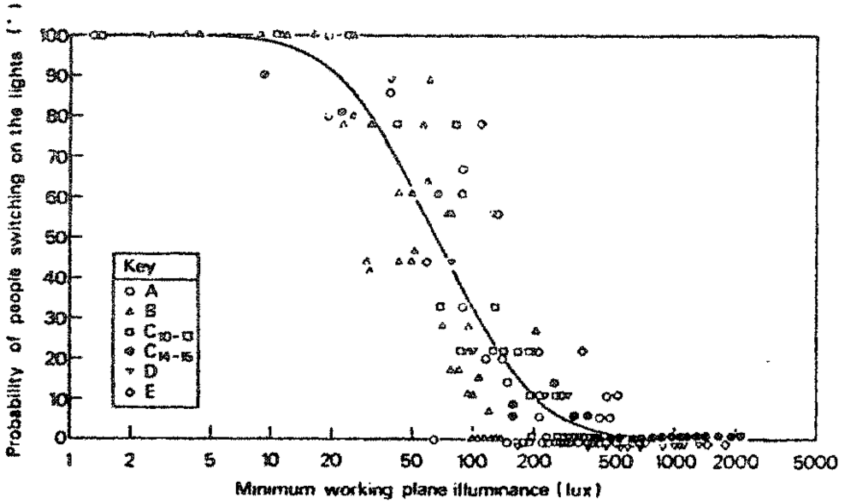


Fig. 1. Probability of someone turning artificial lighting on in a daylit space—field data from various sources.

$$p = A + \frac{C}{1 + \exp\{-B * [log_{10}(P1) - D]\}}$$

Reference: Hunt, D. R. G. Predicting artificial lighting use - a method based upon observed patterns of behaviour. *Light. Res. Technol.* (1980).

Future Plan

- Occupancy Simulator
  - Validation with measured data
  - Support complex cases with a large number of spaces and occupants
  - Improve run-time performance with parallel computing
- obXML
  - Add annotations to the schema
  - Develop a library of occupant behavior models in obXML
  - Consider constraints of multiple behaviors (e.g. turn off HVAC if opening windows)
  - Explore potential integration of obXML with BIM
- obFMU
  - Develop an Application Guide
  - Improve EnergyPlus FMI: (1) removing memory limitation, (2) supporting FMI 2.0 standard
- CERC 2.0 project
  - Application of these tools and integration with building control systems
- Collaboration
  - IEA EBC Annex 66
  - ASHRAE MTG.OBB

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  - University of Strathclyde, UK

Group photo of the Annex 66 participants at the 2nd Experts Meeting at KIT, Germany

How you can help us to improve these tools?

- Try them and provide feedback
- Provide data for validation
- Propose new features
- Use the tools ☺
- Join our future development

Questions

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More Information

Building Technologies Office, USDOE:
http://energy.gov/eere/buildings/building-technologies-office

U.S.-China Clean Energy Research Center (CERC): www.us-china-cerc.org

CERC Building Energy Efficiency Consortium: cercbee.lbl.gov

CERC-BEE occupant behavior research project: Behavior.lbl.gov

Occupancy Simulator: Occupancysimulator.lbl.gov

IEA EBC Annex 66: Annex66.org