



Continuous and Real-time Sensing of Occupant Satisfaction with Indoor Ambient Factors

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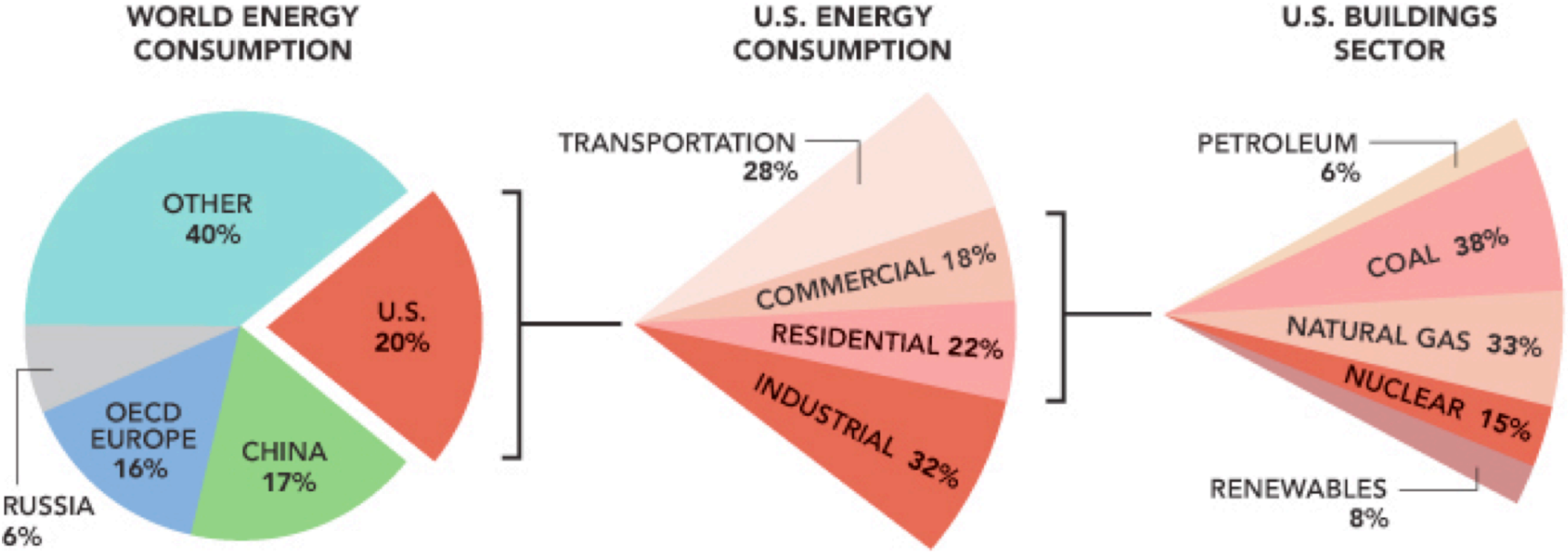
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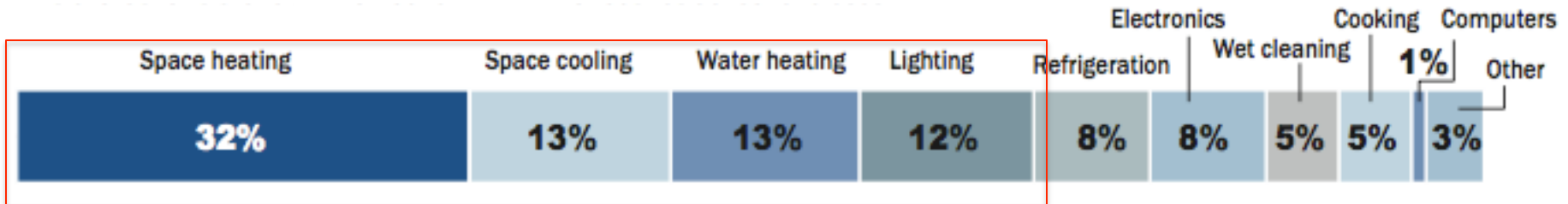


Building Energy Consumption

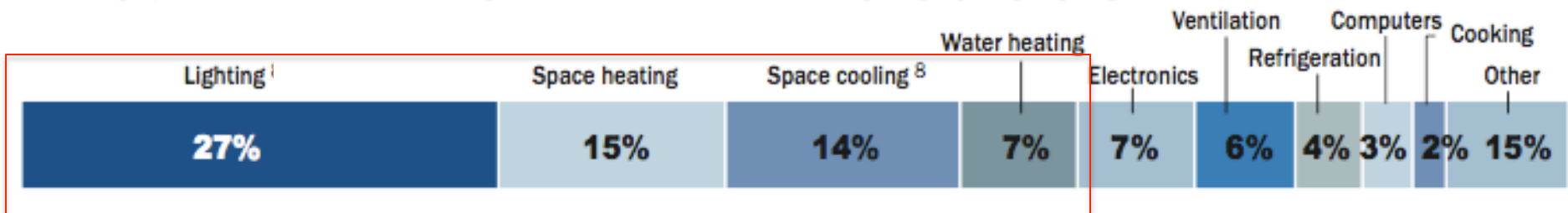


Source: Buildings Data Book, DOE, <http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx>

Energy Consumption in the U.S.



Residential Energy Use

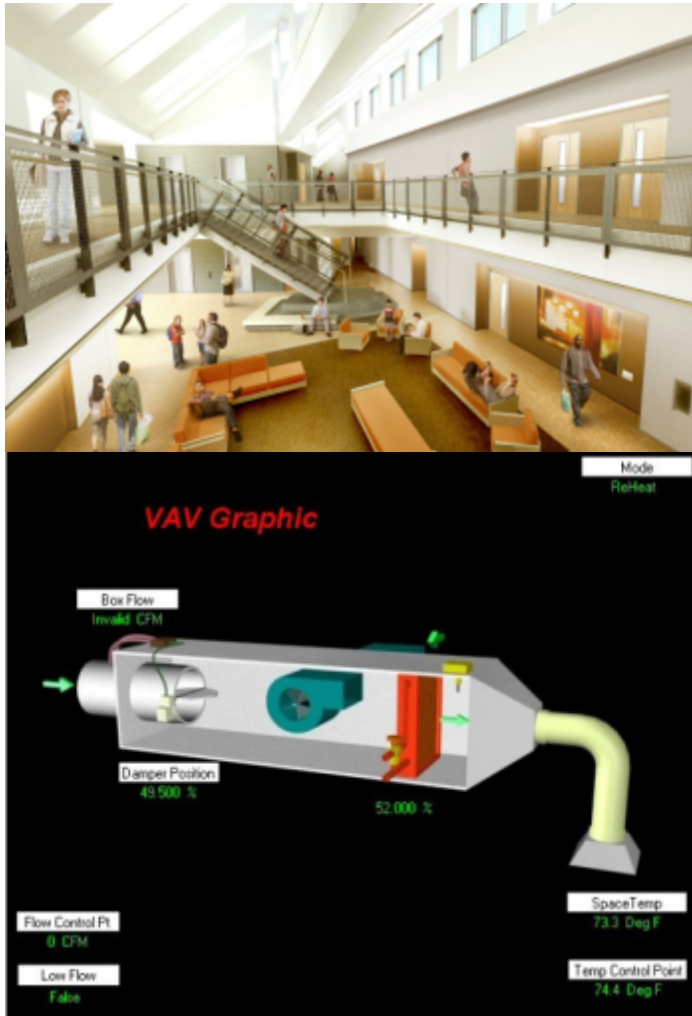


Commercial Energy Use

Roughly 87% of today's buildings will still be used in 2050, composing an estimated 70% of the building stock

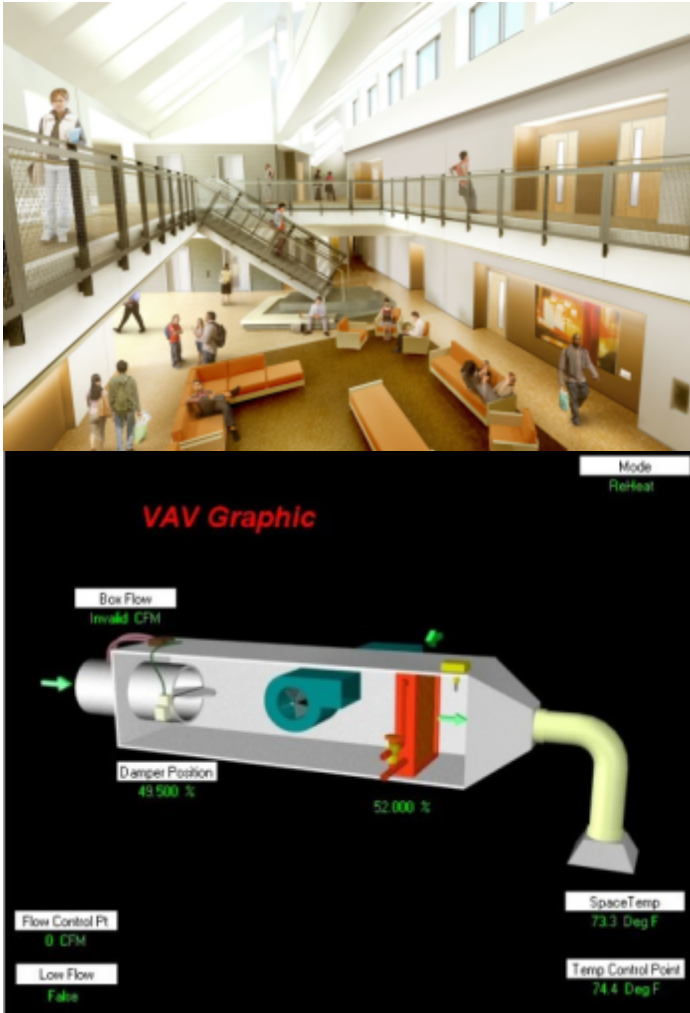
Source: Energy Data Book (2007); EERE, U.S. Department of Energy

Energy Operations



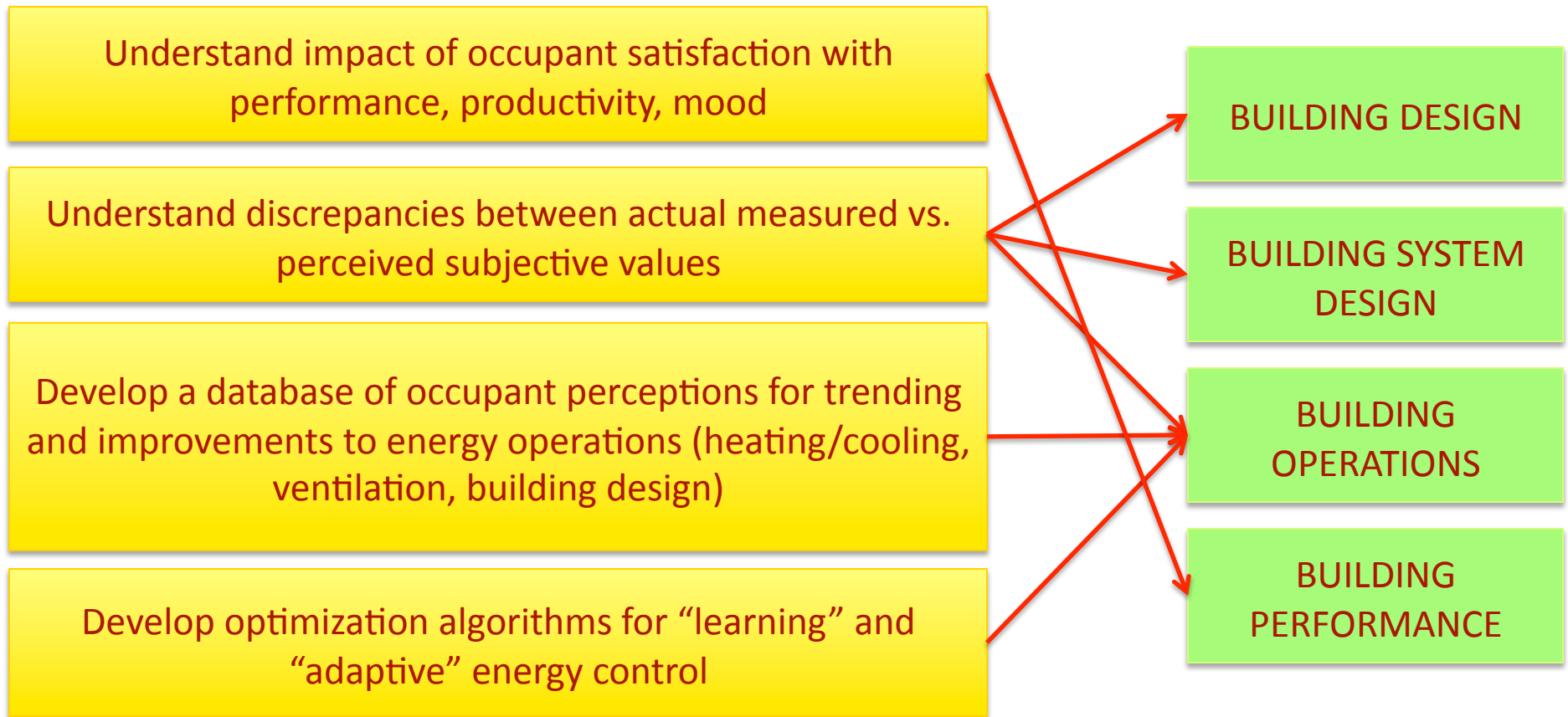
- Currently energy systems are operated for the *peak opposed to optimal*
- Facility manager is forced to “*play it safe*”, resulting in sub-optimal operations
- Occupant comfort is based on *predefined standards*
- Standards are based on *one time surveys or limited experiments* and individual occupant complaints

Comfort Estimation



- Occupant comfort ranges are found to be larger and more forgiving than predicted ranges
- Weak and context dependant correlations between code-defined comfort ranges and occupant reported comfort ranges
- Research proves that there is great potential in improving comfort level
- Energy consumption could be reduced, while improving/maintaining occupant comfort

Energy Efficiency



Participatory Data Sensing



Mobile triangulation brings up a list of three nearest buildings



Participatory Sensing



Occupant Profile

Ambient Factors

Enter email (optional):
e.g. myemail@usc.edu

Select profile:

- Faculty/Staff/Researcher
- Instructor
- Student

Occupant Preferences

Ambient Factors

Enter email (optional)

KAP

1st

103

cooler warmer
Temperature

dimmer brighter
Lighting

less more
Airflow

OK

Supplementary Data for Energy Analysis

Ambient Factors

What kind of clothing are you wearing?

Top

- Short Sleeve Shirt
- Long Sleeve Shirt

Bottom

- Jeans/Long Pants
- Shorts/Skirt/Dress

Warm clothing

- Sweater or Sweatshirt
- Heavy Coat

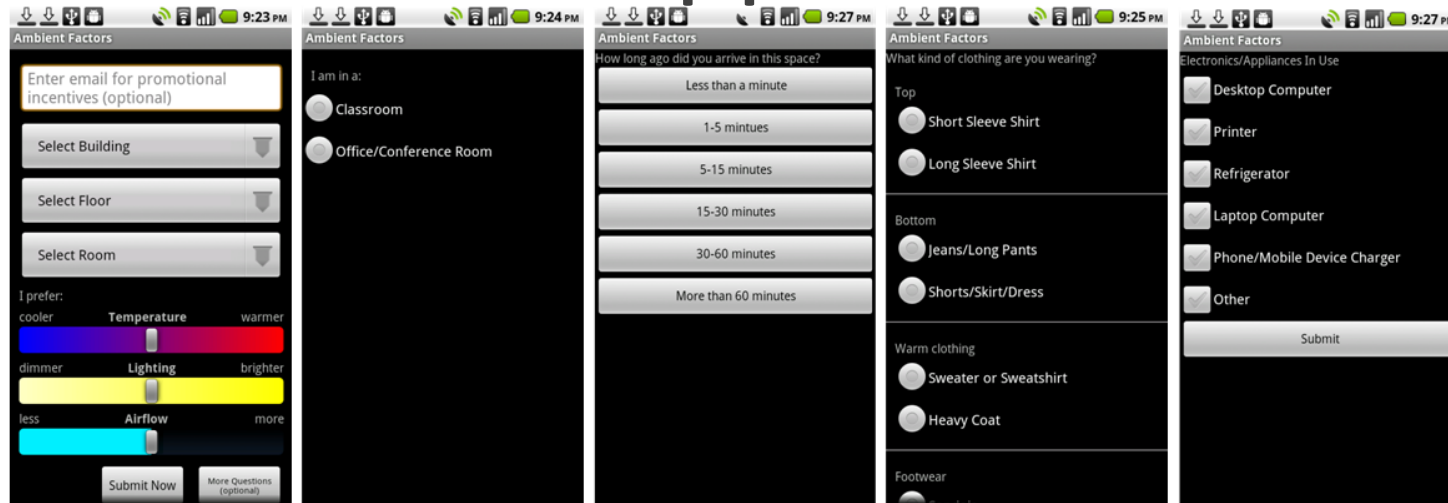
Footwear

Electronics/Appliances In Use

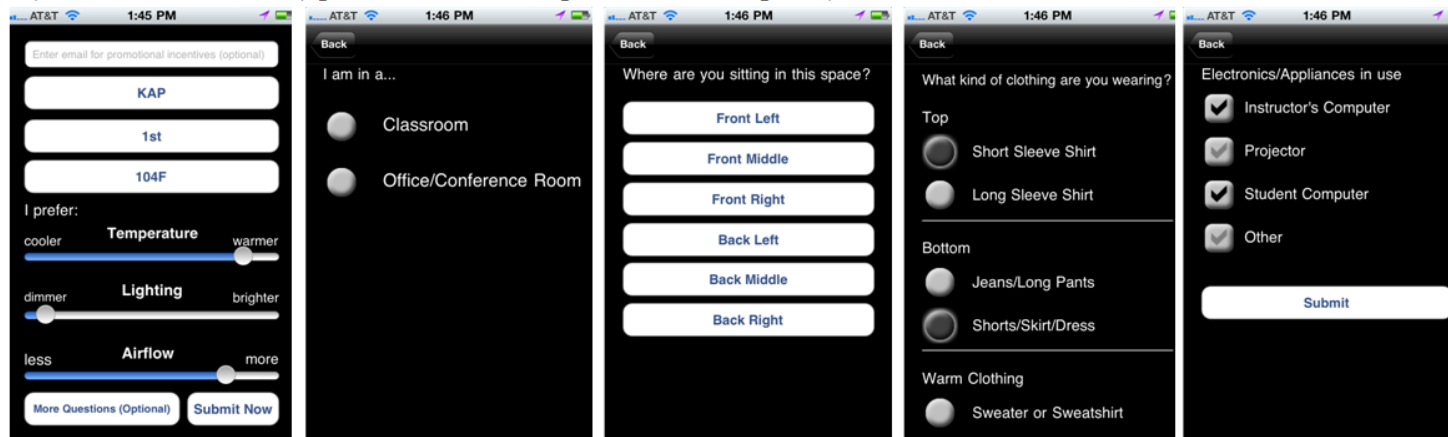
- Desktop Computer
- Printer
- Refrigerator
- Laptop Computer
- Phone/Mobile Device Charger
- Other

OK

Mobile Apps




a) Android version (optional module for permanent occupants)



b) iPhone version (optional module for temporary occupants)

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AmbientFactors
USC - ILAB

INSTALL

OVERVIEW USER REVIEWS WHAT'S NEW PERMISSIONS

Description

The AmbientFactors application has been designed to collect buildings occupants' preferences about ambient factors including temperature, lighting and air flow. In addition, it asks for some optional information regarding the clothing level and appliances in use. The application covers University of Southern California (USC) campus buildings. The occupants feedback is used in implementing adaptive control strategies for temperature, lighting and airflow. Accordingly, using the application, buildings' occupants provide valuable information which leads to occupant comfort increase and building energy consumption decrease.

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ABOUT THIS APP

RATING:
★★★★★

UPDATED:
March 7, 2012

CURRENT VERSION:
1.2

REQUIRES ANDROID:
1.0 and up

CATEGORY:
Education

SIZE:
117k

PRICE:
Free

CONTENT RATING:
Low Maturity

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AmbientFactors

By USC

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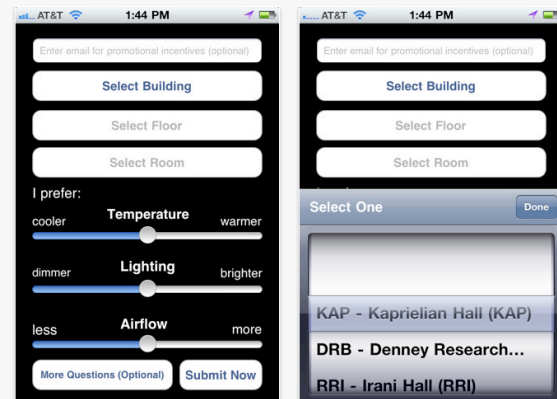
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[AmbientFactors Support](#)

[...More](#)

iPhone Screenshots



[Visit Developer's Website](#)

App Screenshots



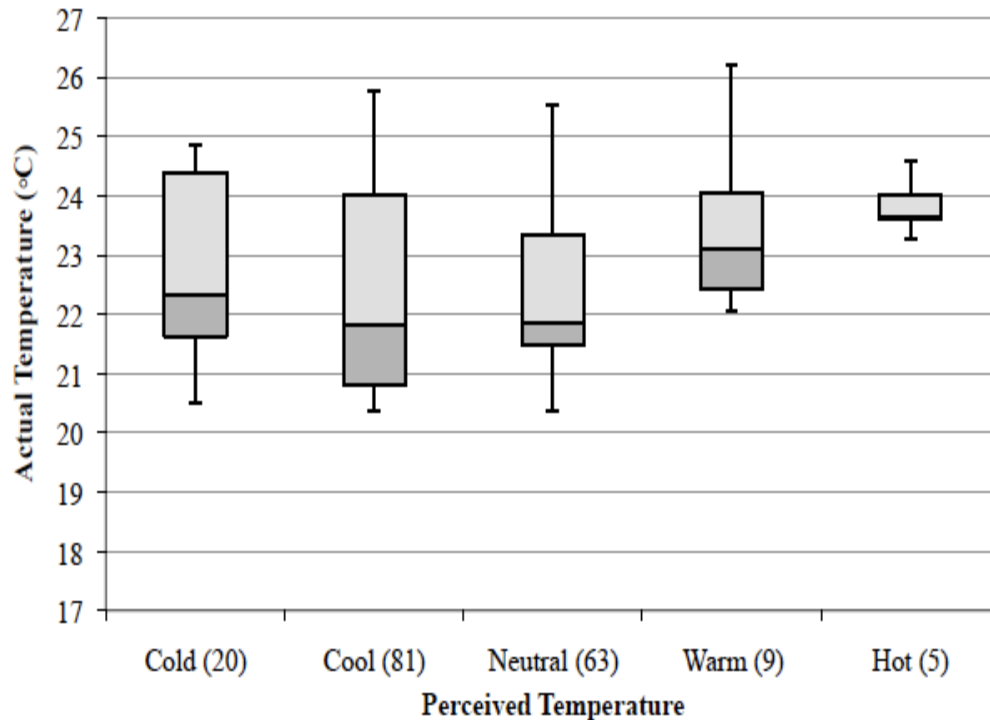
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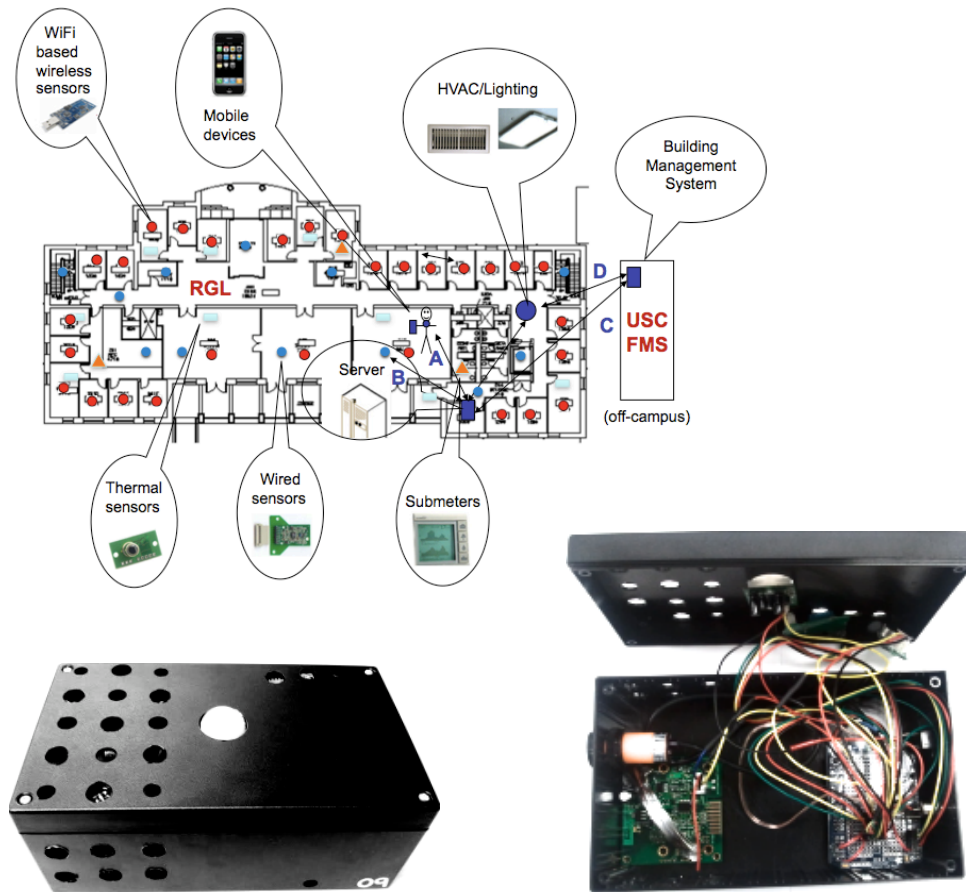
Comfort Estimation



- Ten days - eight rooms
- ~ 65% of occupant perceptions of temperature differed from the neutral condition
- Could be due to the malfunctioning sensors or mismatch between comfort ranges /set points

Jazizadeh F, Kavulya G, Klein L, Becerik-Gerber B. (2011) "Continuous Sensing of Occupant Satisfaction with Indoor Ambient Factors", *ASCE Workshop of Computing in Civil Engineering, June 19-22, 2011, Miami, FL*

Building Level Energy Management System

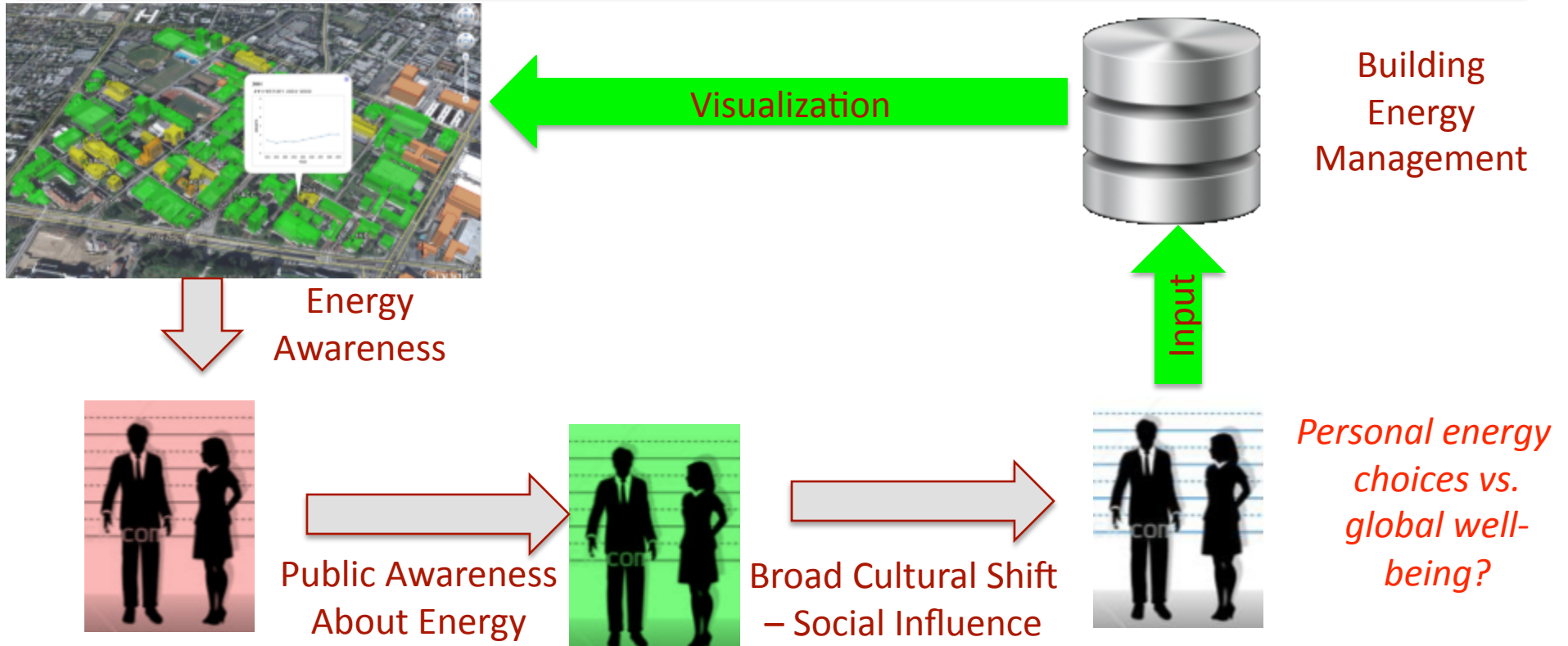


- 50 permanent residents (staff/faculty/grad students) and more than 2000 temporary residents
- 64-wired sensors
- 500+ WiFi-based wireless sensors (temperature, humidity, light, CO2, sound, magnetic, and motion sensors) deployed in 60 moveable sensor boxes and 100+ actuators
- 10 sub-meters (sub-floor, floor and building level for measuring energy consumption of lighting, receptacles, HVAC, elevator, and emergency power)

Energy Literacy



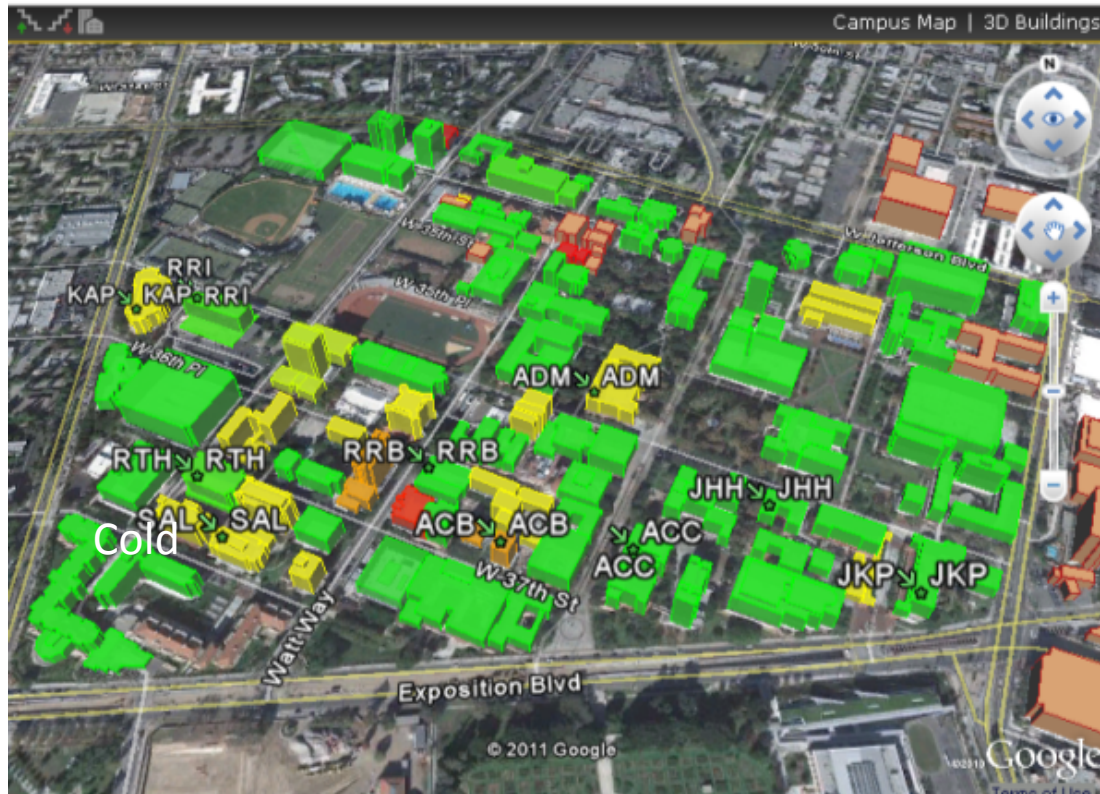
Tangible energy awareness through social influence



Real-time sharing and visualization of ambient features for immediate use



Data Visualization



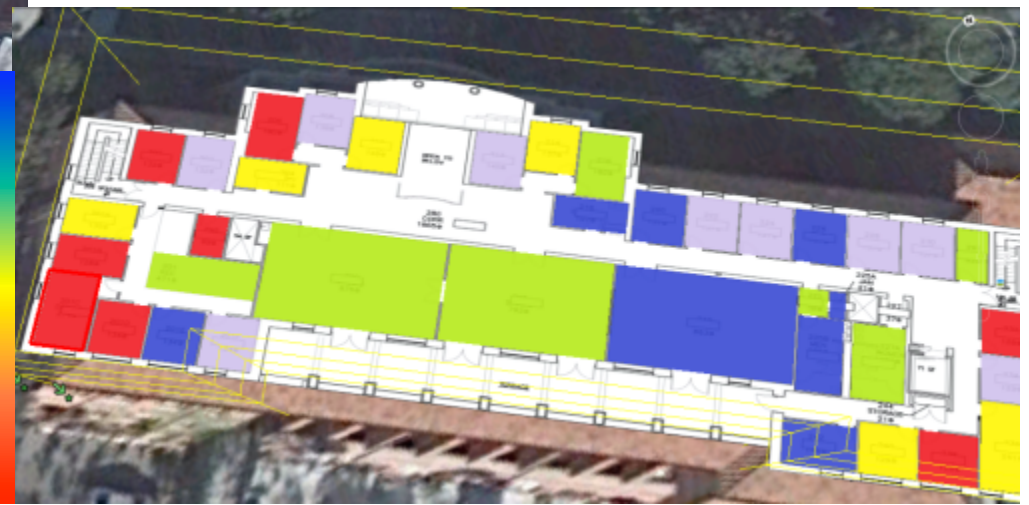
Energy consumption plotted in 3D for influencing occupant behavior



Data Visualization

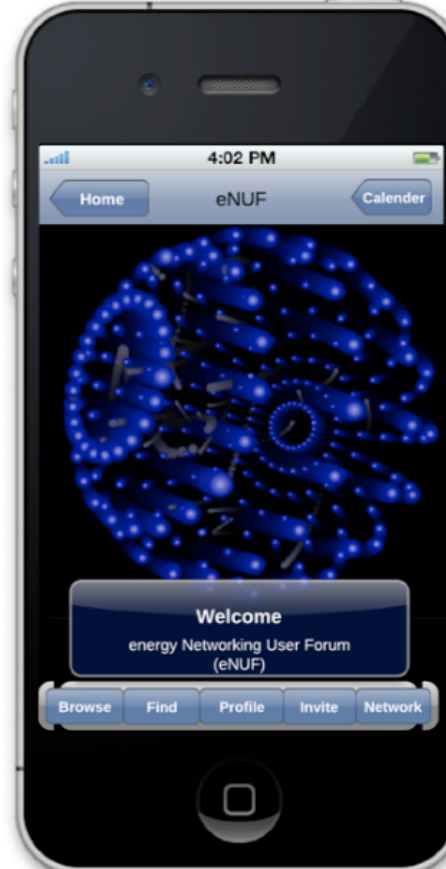


Occupants input mapped on 3D building models and floor plans



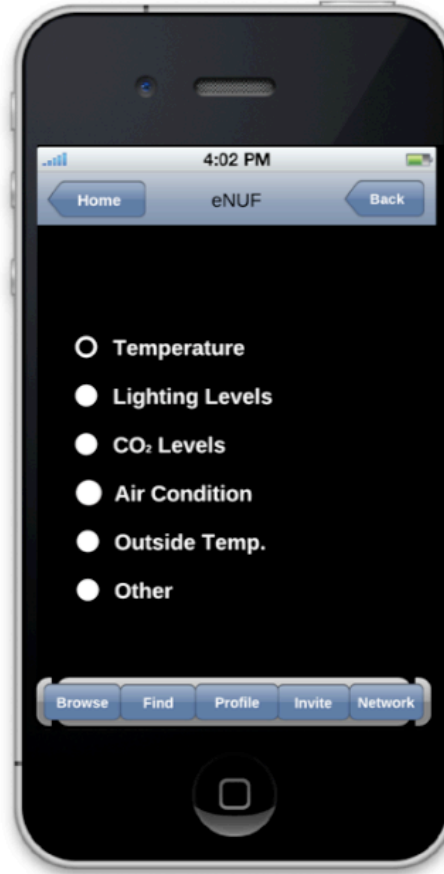


Energy Networking User Forum



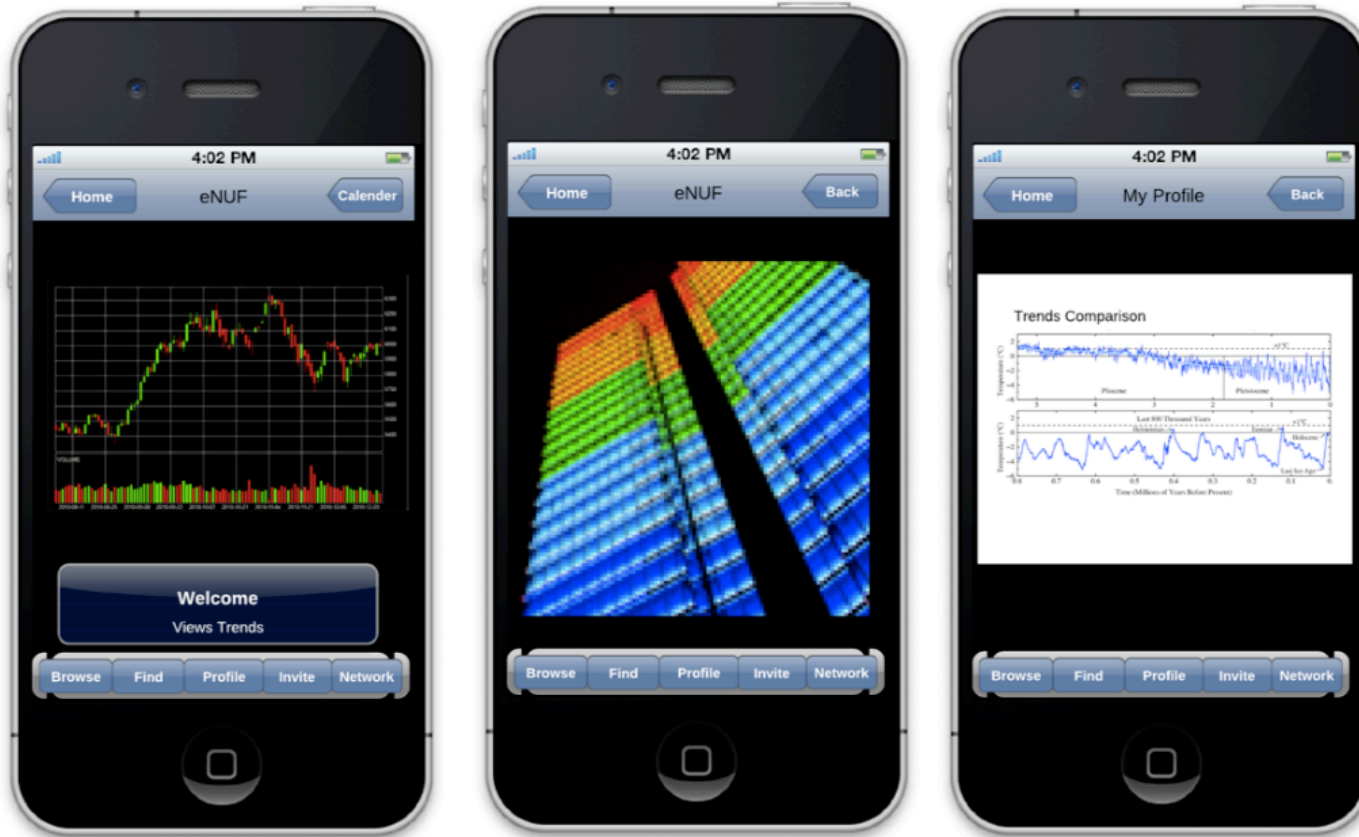


Energy Networking User Forum





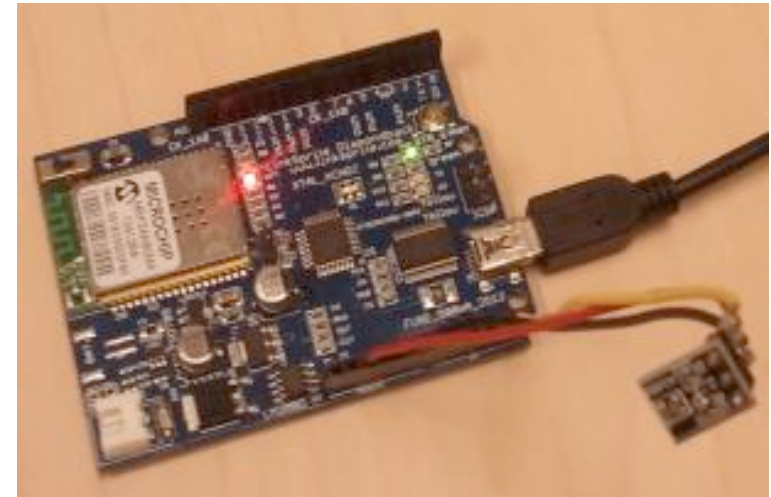
Energy Networking User Forum



Occupant Feedback



- Focus on the contribution of building occupants in energy reduction
- Occupants are asked to reduce lighting level during the day without compromising visual comfort
- Assess the influence information on occupants' behavior towards energy conservation:
 - Reminding to reduce lighting w/o any supporting information
 - Energy consumption w/Environmental information are provided to encourage lighting level adjustment
 - Peers/colleagues ' tendency to reduce lighting level is revealed to all occupants to use social influence for energy consumption reduction



Changes in occupants behavior towards energy conservation is monitored by wireless light sensors which are used to measure the electricity consumption indirectly

Occupant Feedback



- Areal-world test scenario; a pilot sample of participants (staff on campus)
- To investigate the impact of different types of information for changing occupant behavior

Test Group I: no additional information, simply ask to reduce the level of lighting

Test Group II: information including participant's own energy use, rate, and environmental motives

“By reducing (dimming) the lighting level in your office, you can reduce the total building energy consumption. If you agree, the annual energy savings at the building level are 26000 kWh on average, which is equivalent to the reduction of CO2 emissions of 2.2 homes for one year and greenhouse gas emissions avoided by recycling 6.2 tons of waste.”

Jazizadeh F, Kavulya G, Kwak J, Becerik-Gerber B, (2012) “Human-Building Interaction for Energy Conservation in Office Buildings”, CRC 2012: Construction Research Congress, May 21-23, 2011, West Lafayette, IN

Occupant Feedback



Table 3: Lighting Negotiation Results (*: $p < 0.1$)

	Avg. Accep. Rate (%)	User Rating (Max: 5.0)
Group I	28.79 (11.03)	3.82 (0.26)
Group II	68.18 (9.65)	4.18 (0.18)
Mean Diff.	39.19*	0.36



Energy Conservation

- By increasing energy awareness and literacy, occupants could contribute to **sustainable** environments
- Energy consumption could be adjusted by using **adaptive control** mechanisms and **occupant preferences**
- System improvement highly depends on **collective endeavor of occupants**
- iCampus infrastructure is a platform that can dramatically **improve public awareness**
- **Green behavior through social reputation** could be facilitated by social capabilities of iCampus platform





Students & Collaborators & Sponsors



Farrokh Jazizadeh



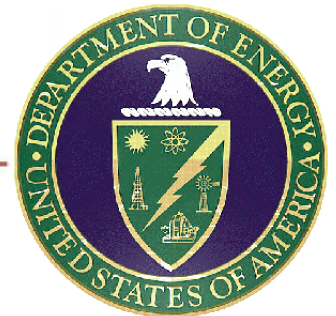
Geoffrey Kavulya



Nan Li



Zheng Yang



Award number:
DE-EE0004019
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Thank you!

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