ARPA-E Advanced Occupancy Sensors for Better Buildings Workshop

NREL Test Facility

Martha Symko-Davies, PhD

July 13, 2016
Energy Systems Integration optimizes the design and performance of electrical, thermal, and fuel pathways at all scales.

Start Small, Then Go BIG

Energy Informatics: Linking Data to Knowledge to Control

Scale

Appliance (plug)
Building Vehicle (meter)
Campus Subdivision (feeder)
Community (substation)
Area (service territory)
Region (balancing area)
Nation

Complexity

Electricity
Fuel
Data
Thermal
A Design Process for Clean Energy

Hardware Testing
- PV Simulator
- Load Banks
- Grid Simulator
- Devices Under Test (e.g. inverter, energy storage, EV, loads)

Modeling & Simulation
- Utility Substation
- Subdivision with PV at end of circuit

Field Deployment

Continuous Learning and Improvement

Human Services
- Mobility
- Comfort
- Goods
- Connectivity
Energy Systems in the loop

- Load Banks
- Grid Simulator
- Devices Under Test (e.g., inverter, energy storage, EV, load, etc.)

**Scale Up Experiments via HPC**

**Hardware Testing and Validation**
- Solar Simulator
- Human Services
  - Mobility
  - Comfort
  - Goods
  - Connectivity
- Devices Under Test (e.g., inverter, energy storage, EV, load, etc.)
- Load Banks
- Grid Simulator

**Modeling & Simulation**
- Visualization Interface
- HIL I/O Interface

**Validation with Field Data**

**New Specifications for Hardware Development**
C-Suite

Re-envisioning building-to-occupant interactions through human subject testing

Precision control of variables contributing to human comfort and performance

Aggregation of individual flexibility to the design and optimization of energy systems

Evaluate potential system impacts of personalized comfort systems

Build understanding for the design of field experiments

Improving comfort and productivity while maintaining or reducing energy use and environmental impacts
C-Suite Details

- Occupied space with tightly-controlled environmental conditions
- Independent Variables [heating/cooling/humidity/illuminance/sound/airflow/...]
- Temperature ramping rate (0.5°F / minute)
- $T_{\text{range}} = (57°F – 90°F)$
- Two 16’ x 8’ sections
- Removable dividing wall
C-Suite Monitoring

Monitoring:

- Dry-bulb air temperature
- Relative humidity
- CO2 concentration
- Visible imagery
- Thermal imagery
- 3D dot-field data
C- Suite

Advanced Imagery
- Wifi
- KINECT
- FLIR

Connected Data Acquisition System
- NATIONAL INSTRUMENTS

Personalized Comfort System
- Tempronics

Android Interface
- 4G LTE

Cloud Backend & Web Interface
- MongoDB

Opportunity/Impact Assessment
- Energy Plus

NREL Proprietary Information. For NREL-DOE internal use only. Do not distribute.
Energy Systems Integration Facility (ESIF)

- NREL’s largest R&D facility (182,500 ft² /20,000 m²)
- Space for 200 NREL staff and research partners
- 15 state-of-the-art hardware laboratories
- Integrated megawatt-scale electrical, thermal and fuel infrastructure
- High performance computation and data analysis capabilities
- 2-D/3-D advanced visualization

http://www.nrel.gov/esi/esif.html
Research in the Systems Performance Laboratory develops and integrates smart technologies, including distributed and renewable energy resources and smart energy management. The 5,300-ft² laboratory is designed to be highly flexible and configurable to enable a range of smart power activities—from developing advanced inverters and power converters to testing residential- and commercial-scale meters and control technologies.

**Lab Functions**
- Home- and Community-to-Grid interactions & load dynamics
- Building system interoperability
- Building islanding
- Development & testing of circuits and power electronics components used in renewable energy integration

**Major Lab Equipment**
- AC power supplies
- Small grid simulators
- Connections to REDB
- 3 homes of major & minor appliances, EVs, PV and smart components
- Opal RT & RTDS Hardware-in-the-Loop Systems
Characterization of HVAC Load Shift

- Simulation on Peregrine of 13-node IEEE test feeder with 20 homes
- One home: air conditioner replaced with hardware in Smart Power Lab (SPL)
- EnergyPlus simulation of home in SPL
- HEMS controlling air conditioner in the lab
Effective Demand Response Shifts Cooling Load Earlier in Day

And peak cooling-load increases!

Home Energy Management Systems

Nascent and growing market
- Limited capabilities; more intelligence appearing (focused on thermostat)
- Significant academic research activity

Schedules operation of appliances and DERs
- e.g., thermostat setpoint, charging rate, on/off

Co-optimizes multiple objectives
- e.g., comfort, cost, energy use

Based on inputs
- Preferences: e.g., desired air/water temperature, EV charge and dishwasher completion time
- Electricity price & weather forecasts, DR request
- Sensors: e.g., temperatures, lighting level

Opportunities for additional sensor inputs to HEMS:
- Distributed occupancy and air temperature sensors → reduce heating/cooling required
- Water flow sensors → reduce water heater waste heat (& leak detection)
- (Non-intrusive) circuit level power sensors → improve on-line system identification & performance
For More Information

Martha Symko-Davies
Laboratory Program Manager, Energy Systems Integration
National Renewable Energy Laboratory
Mail Stop RSF 050, 15013 Denver West Parkway
Golden, CO 80401 USA
+1-303-384-6528(phone)
Martha.Symko.Davies@nrel.gov (email)
http://www.nrel.gov/esi

Energy Systems Integration
Accelerating the Clean Energy Future