NREL
NATIONAL RENEWABLE ENERGY LABORATORY






ARPA-E Advanced Occupancy Sensors for Better Buildings Workshop

NREL Test Facility

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July 13, 2016

Start Small, Then Go BIG

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

Scale

Appliance (plug)

Building Vehicle (meter)

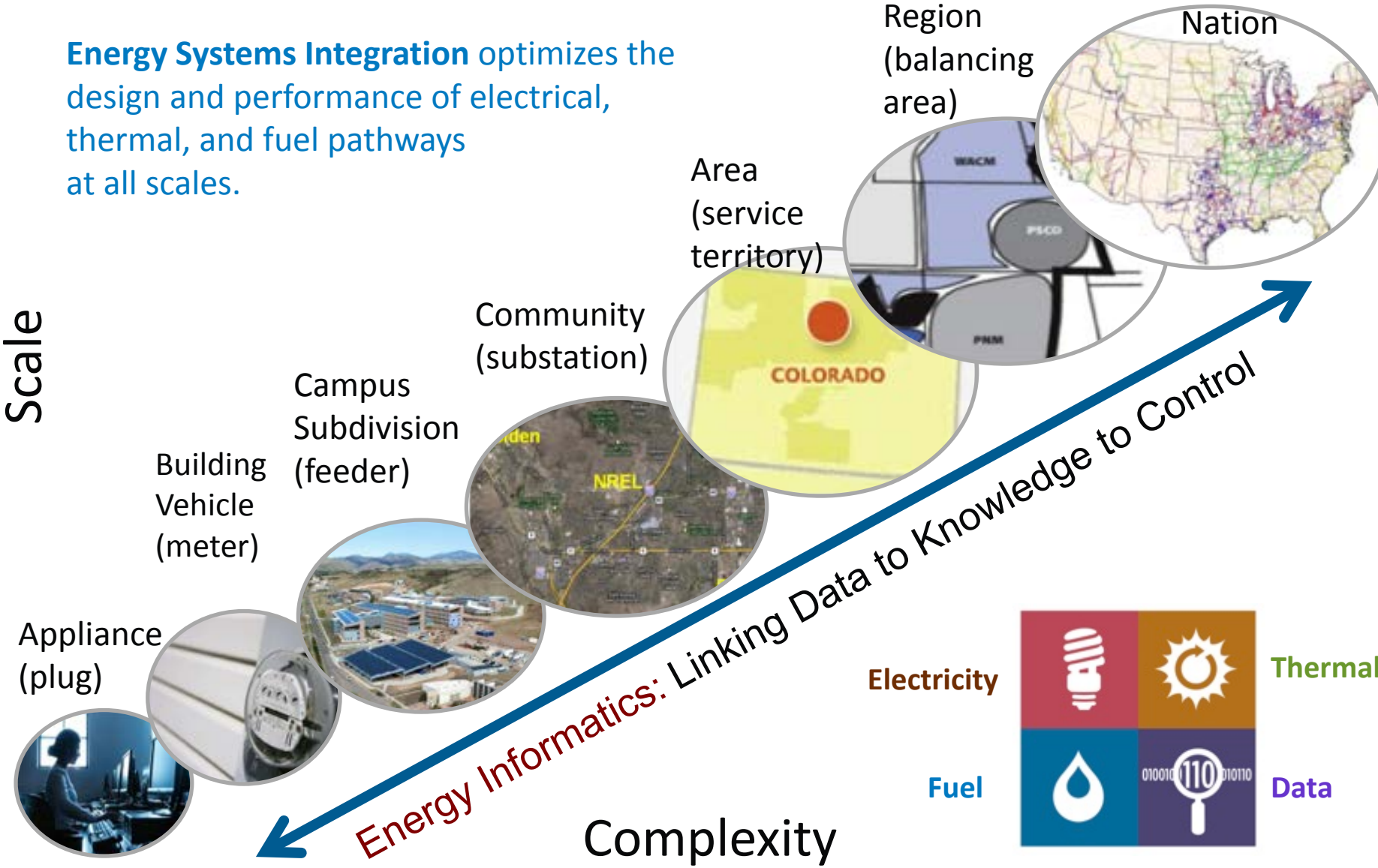
Campus Subdivision (feeder)

Community (substation)

Area (service territory)

Region (balancing area)

Nation



Energy Informatics: Linking Data to Knowledge to Control

Electricity

Thermal

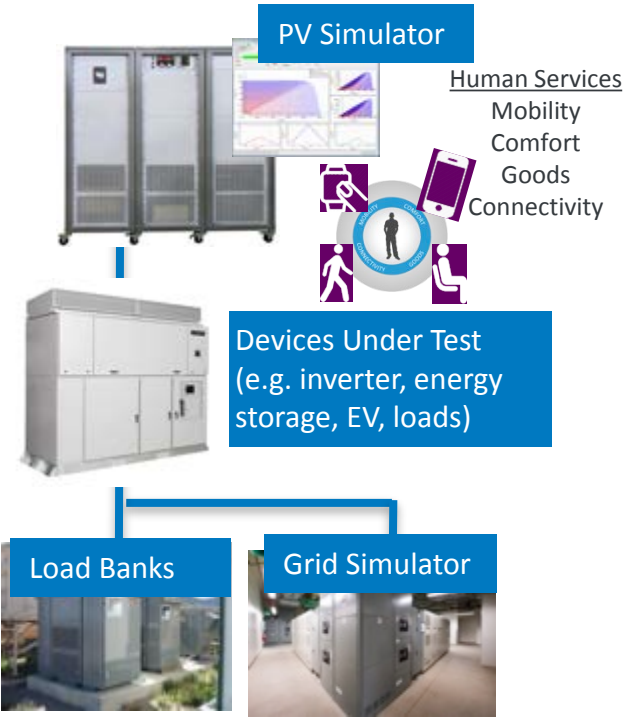
Fuel

Data

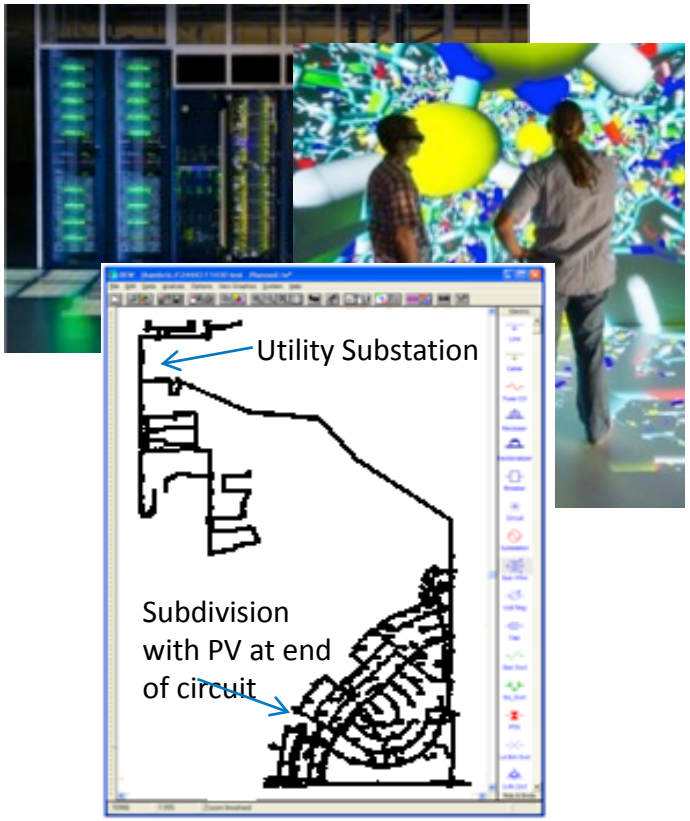
Complexity

A Design Process for Clean Energy

Hardware Testing



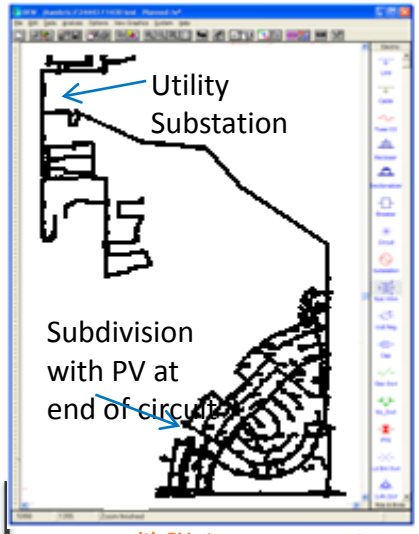
Modeling & Simulation



Field Deployment

Continuous Learning and Improvement

Energy Systems in the loop



with PV at

Scale Up
Experiments via HPC

Modeling & Simulation

Visualization Interface

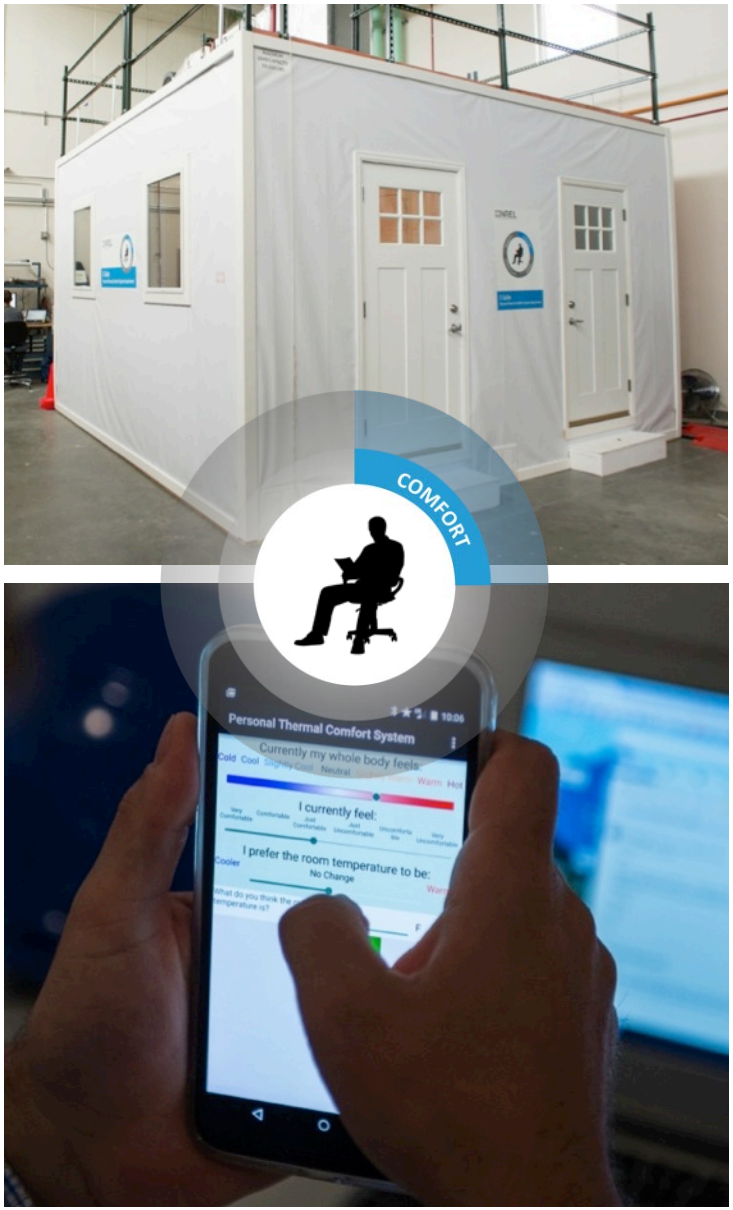
HIL I/O Interface

Validation with
Field Data

Hardware Testing and Validation

New Specifications
for Hardware Development

Enabling Experiment



C-Suite

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

Precision control of variables contributing to human comfort and performance

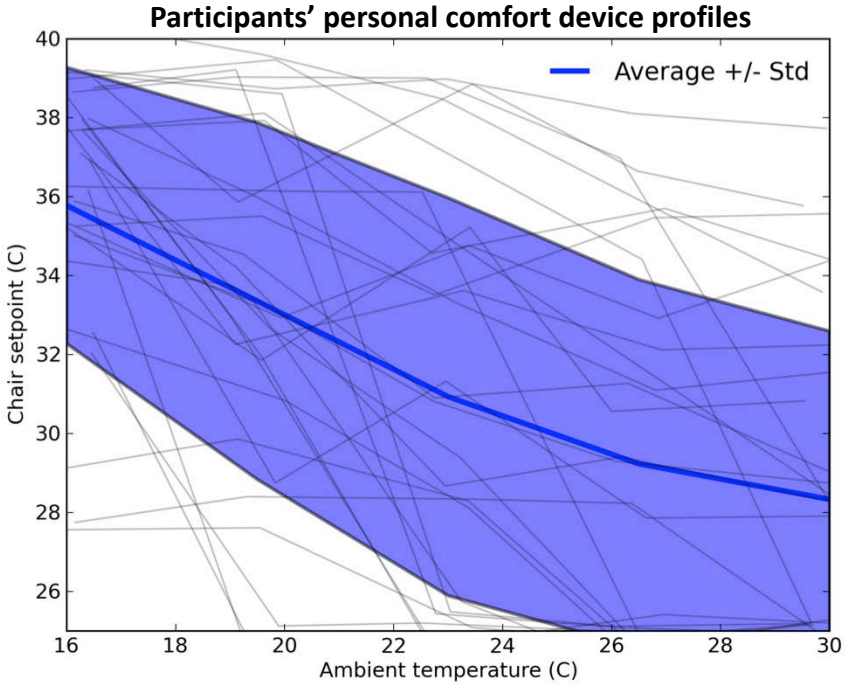
Aggregation of individual flexibility to the design and optimization of energy systems

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



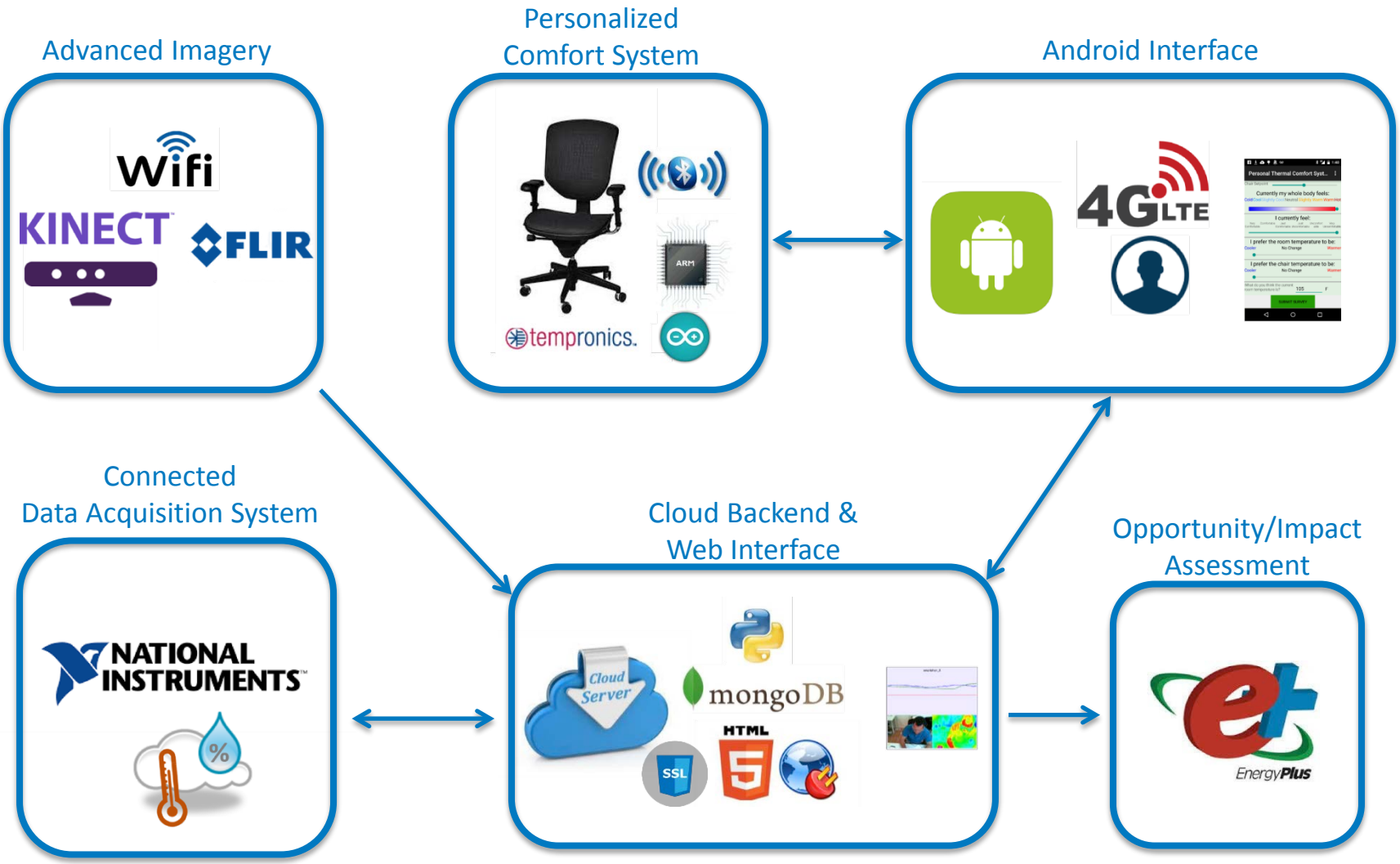
- Occupied space with tightly-controlled environmental conditions
- Independent Variables [heating/cooling/humidity/ illuminance/sound/ airflow/…)
- Temperature ramping rate (0.5˚F / minute)
- T_{range} = (57˚F – 90˚F)
- Two 16' x 8' sections
- Removable dividing wall

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
Personalized
Comfort System
ARM
tempronics.
Android Interface
4G LTE
Connected
Data Acquisition System
NATIONAL INSTRUMENTS
Cloud Backend &
Web Interface
Cloud Server
mongoDB
HTML
SSL
Opportunity/Impact
Assessment
EnergyPlus

Energy Systems Integration Facility (ESIF)

- NREL's largest R&D facility (182,500 ft^2 /20,000 m^2)
- 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

ESIF – Systems Performance Lab

Research in the Systems Performance Laboratory develops and integrates smart technologies, including distributed and renewable energy resources and smart energy management. The 5,300-ft^2 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**

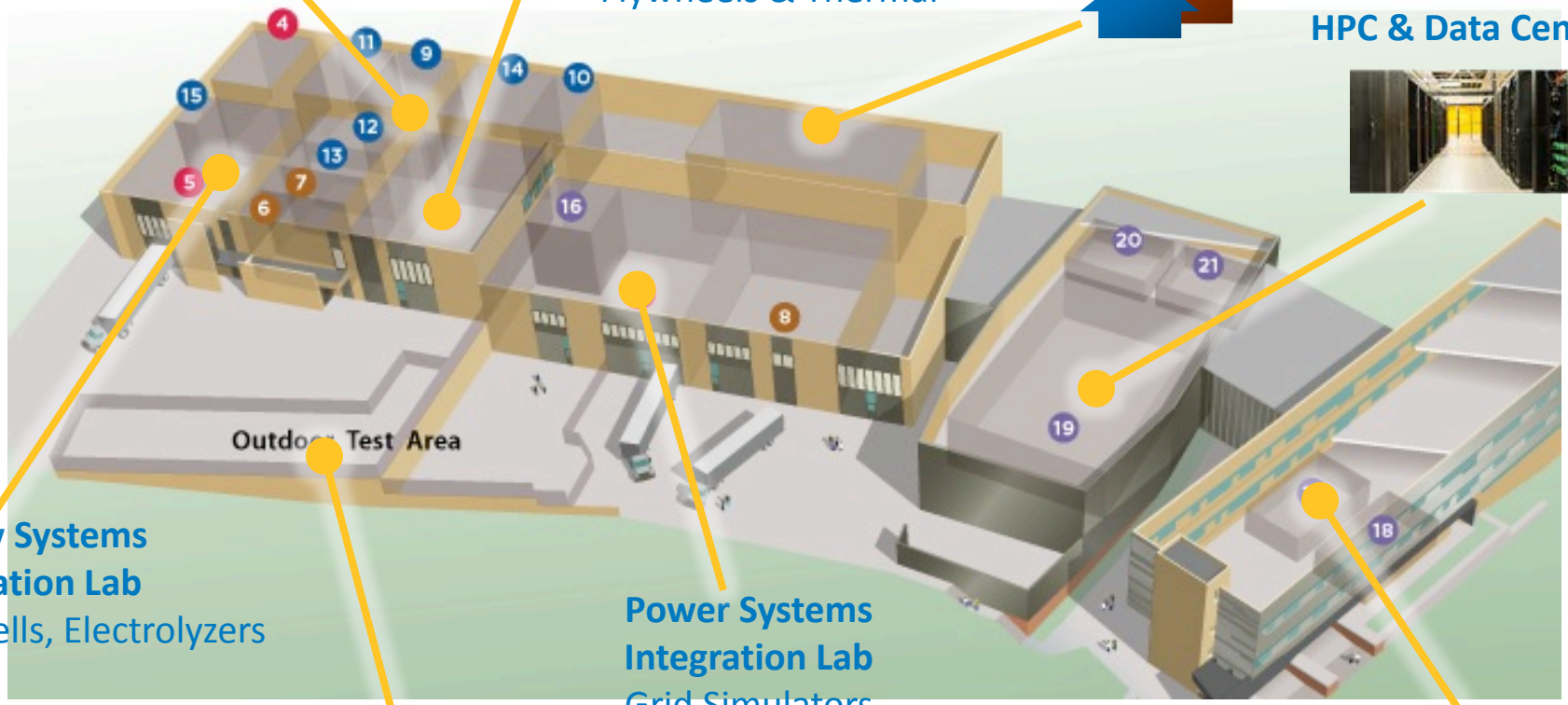
ESIF Laboratories

Rooftop PV & Wind

Energy Storage Lab
Residential, Community & Grid Battery Storage, Flywheels & Thermal

Systems Performance Lab
Buildings & Loads

HPC & Data Center



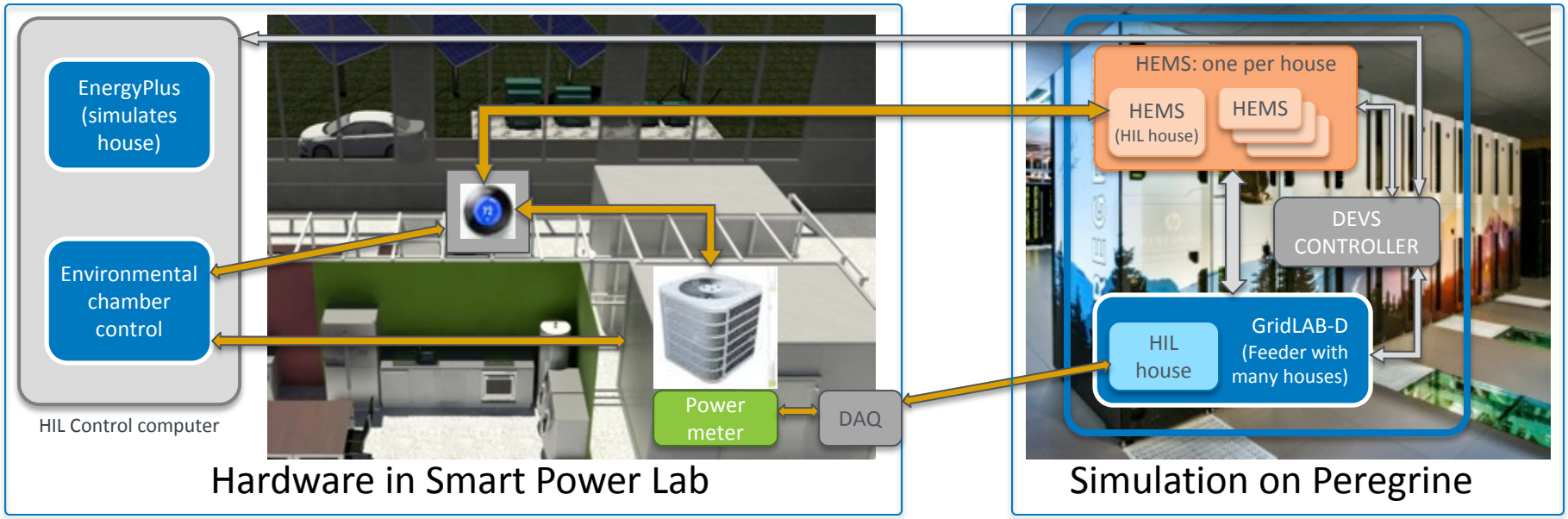
Energy Systems Integration Lab
Fuel Cells, Electrolyzers

Power Systems Integration Lab
Grid Simulators
Microgrids

Outdoor Test Areas
EVs, Power Transformers

Auxiliary Control Room
ADMS Testbed

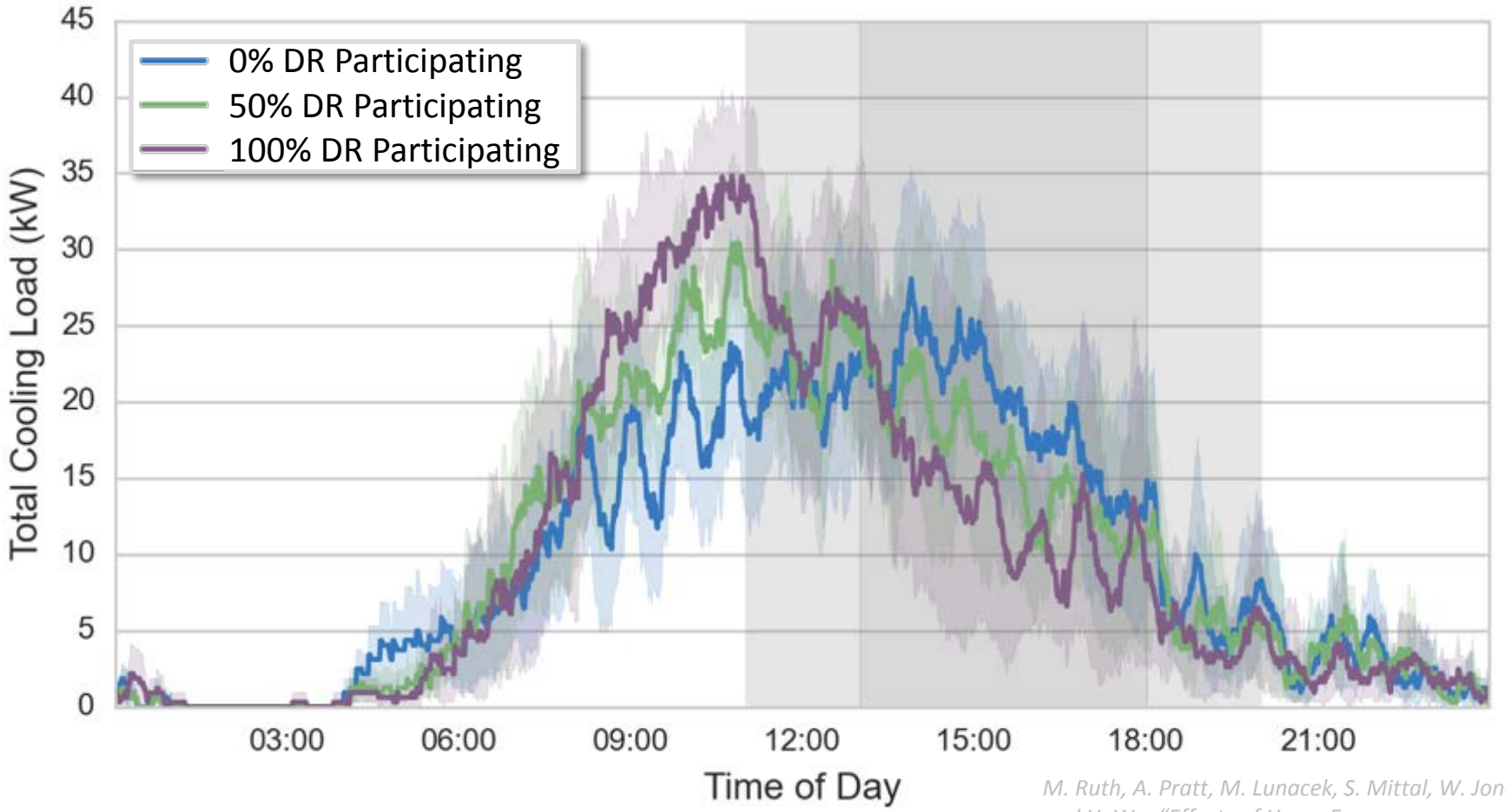
Characterization of HVAC Load Shift



- 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

SPL Multiphysics Hardware-in-the-Loop Study: HVAC DR

Effective Demand Response Shifts Cooling Load Earlier in Day



And peak cooling-load increases!

M. Ruth, A. Pratt, M. Lunacek, S. Mittal, W. Jones, and H. Wu, "Effects of Home Energy Management Systems on Distribution Utilities and Feeders Under Various Market Structures," presented at the CIRED, the 23rd International Conference on Electricity Distribution, Jun-2015.

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

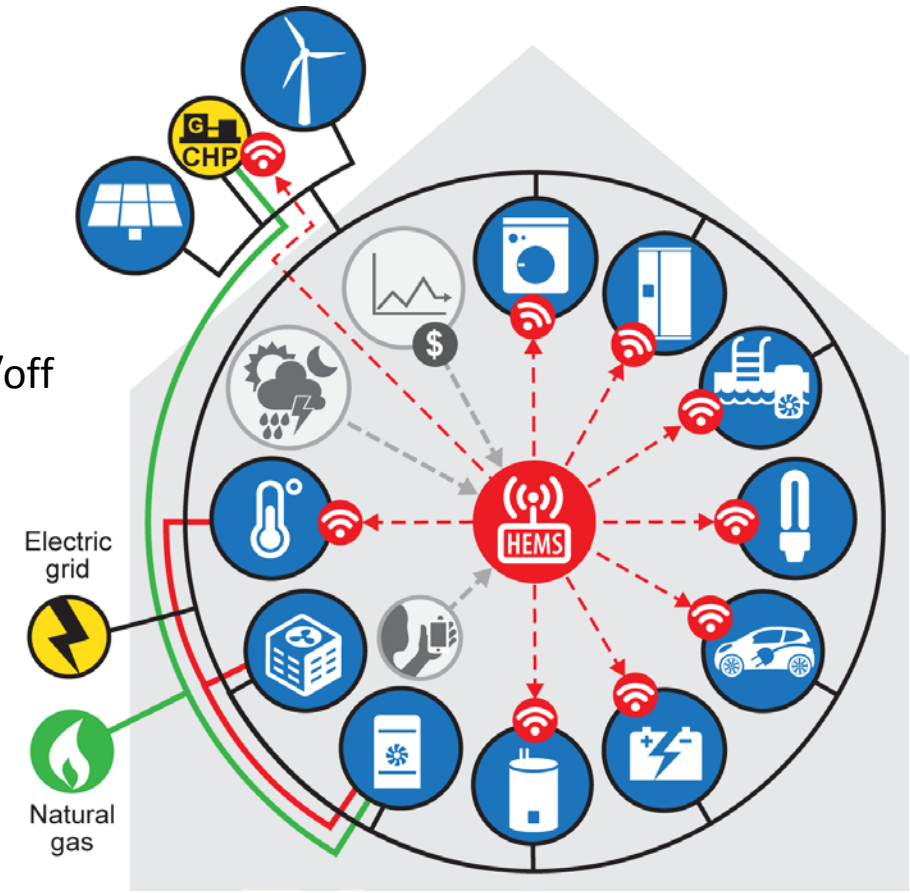
- e.g., thermostat setpoint, charging rate, on/off

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

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http://www.nrel.gov/esi

Energy Systems Integration

Accelerating the Clean Energy Future