ARPA-E Advanced Buildings Workshop

Breakout Group #1:

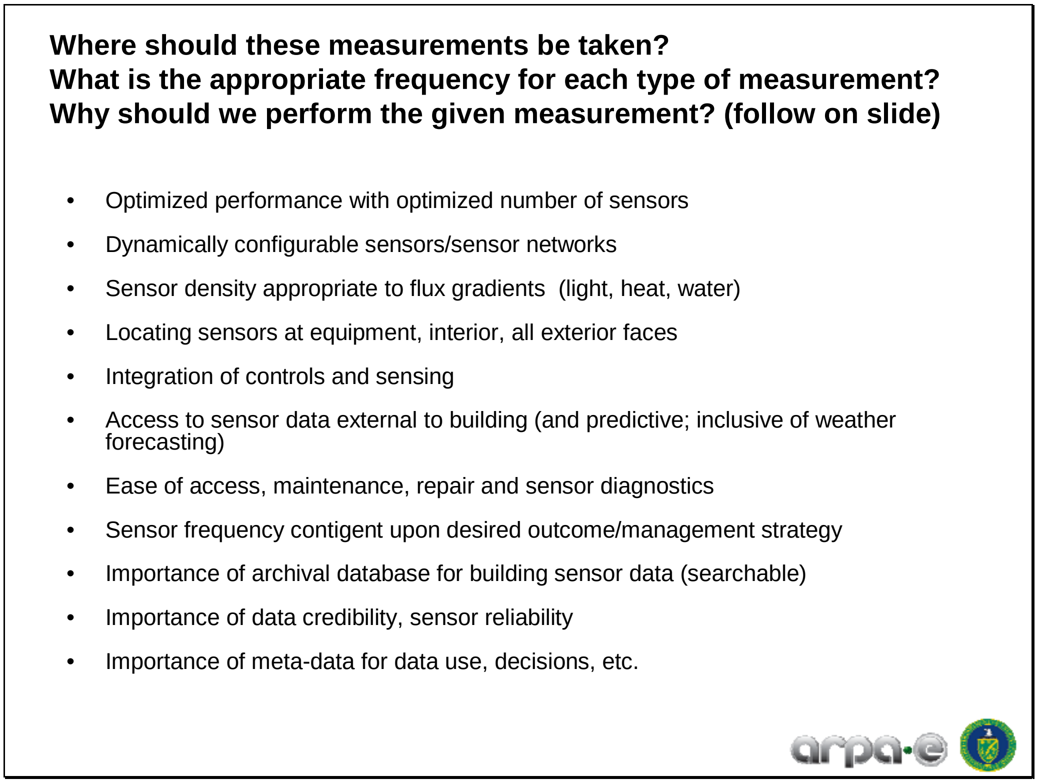
Measurement and Communication
(Chair: Shyam Sunder, NIST)

What are the critical parameters that should be measured in a building?

- Mass flow (air, water, steam)
- Electrical Power (sub-metering for all major equipment; tenant groups)
- Temperature
- Pressure
- Humidity/Moisture
- Building boundary conditions? (windows doors open, closed)
- Light levels
- Occupant and equipment loads, magnitude/location (current and predictive)
- External conditions to building, magnitude/location (current and predictive)
- Heat flow
- Occupancy
- Occupancy comfort
- Indoor environmental quality

What are the critical parameters to measure in a building?

- Occupancy is critical, occupancy load and density- needs to be current and predictive
- Occupancy load location (by zone, by some controllable space)
- Occupancy comfort
- Indoor air quality (health, VOC etc)
- What is happening inside the building?
- What is happening outside of the building- currently and in a predictive way?
- Mass Flow- air, water, steam
- Electrical Power (sub-metering for all major equipment and equipment groups)
- Heat Flow should also be measured in additional to temperature
- You derive heat flow from temperature



Where and why should these measurements be taken? What frequency?

Why?

- Bottom line; want to improve efficiency of the building stock. Provide information/ dashboard some building level information on how things are operating. Operating status of the building (current state)
- Match resources to needs on a local level. Heat, cooling, light, air flow
- It can change incentives. Incentives for changing behavior
- Tracking or monitoring progress against objectives (cost, environment, GHG, meeting environment/energy targets to enable stable controls)- including diagnostics
- Enable optimal control and operation
- Model validation and verification
- Ensure meeting performance standards during service life
- Continuous commissioning
- Interfacing with the grid for peak shaving/load sharing
- Benchmarking data for future design and policy
- Ensure IAQ and occupancy comfort
- Enabling informed decisions on economics of retrofitting

Frequency

- Whatever is appropriate for agreed upon outcome/management strategy
- Importance of archiving database
- How do you synthesize the data into
- How do we deal with data quality, especially if we increase the amount of data- quality of sensor and data become critical
- Sensor reliability/ diagnostics/ believability
- Metadata- what is important about the data- helps to make decisions

Why should we perform these measurements?

- Developing a “dashboard” of building operational status
- Match resources and needs on a local level (heat, light, etc.)
- Incentives for changing behavior
- Providing feedback on external environmental/energy targets
- Enable optimum control and operation (including diagnostics)
- Model validation and verification
- Ensure meeting of performance standards
- Continuous commissioning
- Interfacing with the grid: peak shaving/load sharing
- Benchmark data for future design, policy
- To ensure IEQ and occupancy comfort
- Enabling informed decisions on economics of retrofitting (esp. high ROI)

Where should these measurements be taken?

- Commercial perspective- want the fewest sensors possible
- Optimal location for what the sensor is supposed to do
- More ubiquitous sensing.
- Functions of the building changes, we need to have some system where we can move the sensors as needed. Dynamically configurable.
- Need to gradient information. The density of the sensors should capture the thermal gradients or energy gradients. (Thermal, water)
- Integration of sensing and controls- they have to filter back and forth. Location and frequency needs to be consistent with control methodology
- Locating sensors at equipment interior all exterior faces
- Access to sensor data that is outside the building and is predictive (including weather forecasting)
- Changing loads in anticipatory fashion- need to do it in buildings
- Locations that are easily accessed for maintenance/ repair
- Some way to check on the sensors- sensor diagnostics

In order to precisely and accurately take measurements, what are the present (and needed future) sensor capabilities?

- **How much do they cost?**
  Metric: 2.5yr. Payback to be feasible, generally (?)
- Affordable now: temperature, motion sensor
- Large variability with excessive costs/affordability for advanced functions
- True costs vs. purchased cost: operation of sensors, lifetime of sensors, inclusive of BMS as well

- **What is the fidelity of the collected data?**
  Drift is a big issue for T, CO2, etc.
  Lack of reporting on sensor fidelity
  Need to detect drift in sensors
- Accuracy of data inadequate for advanced functions (gradients)
- Both precision and accuracy need to improve

- **Are they feasible to use in the marketplace?**
- Wireless vs. wired vis-à-vis feasibility in marketplace
- Batteries vs. no-batteries (energy harvesting)
- Drive to move from operator-intensive to fully autonomous

Feasibility

- Wired vs. wireless- wired is feasible for retrofit applications
- Batteries vs. no batteries

What do they cost?

- Costs enough that large owners/operators currently can do it
- It has to have 2.5 year payback
- Large variability in cost with sensors with advanced sensors
- Is there a payback on a VOC sensor- what is the payback (healthcare costs?)
- Difficult to quantify because sensing is an enabling technology hard to quantity. They are part of an energy management system, so the whole EMS has to be in the 2.5payback period
- No building standard on measured performance
- Full time staff to fix sensors- experienced staff required to maintain sensors
- Can we look beyond humans and get these things to fully automated
- What about different levels of sensors for different income levels

Fidelity of collected data? Currently?

- Drift is the big problem for most sensors
- Sensor drift but nobody reports it- lack of reporting
- Systems are not maintained as well as they should be.
- If you measure gradients accuracy is extremely important- precision

Future Sensor Needs

- CO2
- VOC
- Biologics
- Affordable, accurate occupant density sensing by zone (anticipatory)
- Fine-grained equipment loads (zones, etc.)
- Affordable light levels metering appropriate for task
- Personal comfort (comfort/no comfort feedback—challenge of defining comfort in parameters)
- Sensors to monitor and control plug loads (integrated with building electrical system)
- Residential/commercial applications consistent with privacy/security needs
- Sensor communication over IP or existing wires (to use in existing buildings vs. newly built); importance of IT integration
- External

Present capabilities and what is needed in the future

- Sensors that detect CO2, VOC, biological content
- Current sensors only tell you if someone is in the room, not how many. Needs that
- Affordable, occupant/ occupant density sensor methodologies by zone (anticipatory)
- Affordable is the key issue
- Detectors at the door
- You want a leading indicator, otherwise if you are measuring when people come in it's too late
- Light levels (functional light levels at the task)
- Residential applications will need different sensors- privacy, cost
- What about personal comfort (IR cameras) what does comfort mean?
- Software through the controls can do that
- What about sensors as related to plug loads? Huge issue is the plug load, Affordable sensors that are built into outlets, not able to measure plug loads. Have to do it at the plug so it is part of the building system, not at the appliance.
- Why? To understand if they are running past the normal operating hours. Ideally to control it. Monitor and control plug loads
- Security is a huge issue

What modeling capability is required?
Is distributed or centralized processing of data preferable?

- Transmit information or data?
- Developing ways to perform complexity reduction: easy to use, path to automation (for commercially viable systems)
- Modeling of HVAC: need to know equipment, time constants, etc.
- Using BIM for model development
- Developing BIM for existing stock?
- Learning systems to optimize performance, adaptive buildings

- New vs. existing: limited in ability to manage loads, integrate sensing

- Determining hierarchy of decision making wrt control system architecture
- Need to consider collections of buildings at campus, neighborhood, community, and utility scale (for optimizing energy flows, balances)

What modeling capability is required?
What do you transmit? Data or voltage?

- Scalability is the issue. We need to have a modeling capability that is transferable to everyday
- Transfer it to commercial applicability. Complexity reduction/ management
- We want to automate these things as much as possible
- Display/ visualization
- Learning systems to optimize performance
- Need information about the equipment, time constraints
- Building Information Modeling- how do you cost effectively develop a BIM for existing buildings?
- What are the challenges in new vs. existing
- New- you can use a lot of this information up front
- Old- you are stuck with the way the building was originally build., wired sensors in
- **Sensing over existing wireless infrastructure (over power or over IP)- future need**
- IT integration
- Is distributed or centralized?
- Determining hierarchy of decision making of control system architecture
- Not just one building, but collection of buildings

- Don’t just think about buildings in isolation-
- Consider collection of buildings at community and utility scale.

What level of security is needed for these wireless systems to safely and accurately transmit measured data? What is required to make these networks tamper proof?

Matching security of transmitted data to tenant?

Maintaining integrity of security on control side

Integration of building safety, security, and control systems

Real property system

Security-Are there any unique security concerns when we go into the commercial and residential markets?

- If you do it over the net, produces opportunity for people to screw up your controls
- Need metadata to see if your control system is being corrupted
- Maintain integrity of security on control side
- Integration of safety, security and control systems and REAL property systems (for big real estate folks)

What wireless systems will be required to transmit the collected data?
Are the protocols we presently use sufficient (e.g. NIST- Bacnet)? If not, do we need better protocols? What would those protocols include?

- Transmitted information depends upon decision mode (e.g. transmitting all data versus changes in data?)
- Mesh configuration for networks
- Low-bandwidth and high tolerance to individual data point variability (do not require high standards for data integrity)
- Tools for automatic configuration of networks and sensors (up to embedded system design tools and configuration networks)
- Security tradeoff between automation and human control
- Sensor obsolescence? As IT protocols change (3-4 year time horizon), this drives replacement
- Mismatch of sensor lifetime (service life) and communication protocol changeover times (re-do? Replace? Swap?)
- Issues regarding sensor lifetime and need for redundancy and failsafe system operation (robust to failure of individual sensors)

Transmission of data over wireless systems? Do we need better protocols

- Do the present protocols handle this huge amount of data?
- Only send when there is a problem?
- A whole new communications network- a mesh configuration
- You don't need big packets- it's not mission critical
- Relative to a high tech application, Low bandwidth, low reliability relative to mission critical type data transfer
- High tolerance to fluctuations- but still need to know what is good and bad data
- Configuration of networks is complicated- need tools to automatically configure wireless networks
- Security tradeoff between automation and human command
- As we reconfigure we need to know what the metadata is
- Sensor lifetimes? Obsolescence? As IT protocols change, do we need to replace (3-4 years)? Communication. Controls with
- Mismatch of sensor lifetime and communication protocol changeover times (re-do? Replace? Swap?)
- Service life of any component is an issue
- Issues regarding sensor lifetimes and need for redundancy and failsafe system operation (robust

Highest Impact Applications

- Applications with highest potential impact on ARPA-E mission areas:
  - Greenhouse gas emissions reductions; and/or
  - Improved efficiency of power generation and delivery

  -- lighting controls

  --improved efficiency of end-use

  --smart building/smart grid interfaces

  --retrofittability on buildings crucial (retrofit vs. new regarding cost/payoff)

What breakthroughs that are needed?

- Sensors for measurement and communications
- Sensors to predict future performance
- Continuous calibration
- Getting to high speed, high accuracy data
- Lower power consumption
- Smart sensor networks that combine communications and controlling
- Get communities to interact with one another and understand how they affect our building performance/

Key Technical Barriers

Cost
Lack of standards/protocols for technical evaluation
Proprietary vs. standardization (consider interoperability)

Delivery mechanism: how to translate tech. developments to use

Key Technical Barrier

- Cost
- Lack of standards/ technical evaluation criteria
- Proprietary vs. standards
- If you don't standardize you won't have interoperability
- Delivery mechanism : how to translate tech developments

Breakthrough Technologies

- Smart sensor networks that combine communication and control
- Self-calibrating, self-diagnostic systems
- Sensor networks at community and neighborhood level (buildings talking to buildings)

- Sensors for measurement and communication
- Sensors to predict future performance/durability
- Getting to high-speed/real-time, high-accuracy data
- Low power consumption