# Enabling Energy Efficient Building Management Through Reduced CAPEX

ARPA-E Mini-workshop

Breakout #1

# DEFINING THE OPPORTUNITY

# Defining the Opportunity

- **Objective**: Step through the process of selling, designing, specifying, installing, and then commissioning an energy efficient building controller retrofit. Determine the key hurdles that are holding back widespread adoption.
- Questions
  - Which of these steps have the highest cost (lowest hanging fruit)?
  - Is cost not the issue? Do we just have to wait for the technologies to go through the businesses pipeline?
  - What are the current limitations with HVAC controls?
    - Characterize over: big/small, old/new, geography, owned/leased
    - What data is gathered but not fully leveraged
  - What have you found as the key techno-economic hurdles for implementing your research?

# Breakout 1: NOTES

- **Hurdles to widespread adoption:**
  - **A people problem, not cost or design:** Installers will do it the way they want. Every business plan is a little different. How do we make systems so easy that it works no matter how you install it (ease pain of install, tuning)? Traditional model-based control is a non-starter. Perhaps an artificially intelligent system at every level.
  - **Trust of data and paybacks:** Consumers still not convinced of energy savings (despite 1.5 year payback for smart thermostats). In one study, ~9/10 of programmable thermostat users never set programs. Nest may not always be as smart as user (one sensor in big house). Changing engagement with data (a la simplification of travel). Contractors don't want service agreements to be passed up to the equipment manufacturer.
  - **Front end:** Tons of control algorithms out there and people working on operation, not enough good front end.
- **Policy action:** Discussion/disagreement on effectiveness of penalties for missing energy reduction targets on mid-size buildings. No one is accountable for energy use, and it's very hard to prove you're not meeting performance targets. DVR legislation only went through as it's such an easily identifiable thing.
- **Other obstacles/opportunities:**
  - **Standardizing** efficient mapping of data.
  - **Smarter equipment:** Integrating control logic and intelligence into equipment. Grid-integrated controls for flexible loads. New architectures that can be updated throughout life of building.
  - **Phone as BMS:** A few years down the line we could have phones acting as BMS. Make sure you don't use more energy running the computations (in cloud) on status of a light than you'd save by turning the light off.
  - **Standardization of logic/interpreters/frameworks**: Must be capable of speaking to multiple protocols from different manufacturers. Backnet is a communication protocol, not made for building control, and everybody uses it differently. Niagara might have been used differently if it came and not 20 years ago.
  - **Openness:** Black boxes (e.g., Apple's Homekit using Bonjour) may scare off control contractors.

Breakout #2

# THE STRAW-MAN

# The Straw-man

- **Objective**: Determine the feasibility of the straw-man proposal, and discuss specific technologies that could bring each step towards fruition. Alternatively, determine alternate pathways to reach the same efficiency objective.

1. **Building**: 50,000 SF, 4-story office in NE with VAV HVAC. Built 1980.
2. **Constraint**: Keep all existing mechanical systems (ducts, condensers, etc)
3. **Sale**: Lookup in database of similar building to show no-brainer savings
4. **Design**: Merely select interface devices for existing sensors & knobs
5. **Approach**: Embed system into all HVAC system sensors & knobs
6. **Initialization**: Building performs as poorly as before. Slowly, the system autonomously determines system layout, and models comfort & energy.
7. **Operation**: Eventually desired comfort and energy are achieved. Somehow.
8. …
9. **Profit**

# The Straw-man

- **Questions**:

1. **Building**: Does this hold up across all sizes/locations/ages/HVAC types?
2. **Constraint**: Too strict? What is the cost of loosening the constraint?
   Is it even worth installing a smart system on a dumb building?
3. **Sale**: What does it take to convince someone? Can an analogy be drawn to solar PV financing decisions based off of LIDAR and satellite imagery?
4. **Design**: Is it possible to create a single system that can talk to everything?
5. **Approach**: Does system replace or augment existing controller?
6. **Initialization**: How long will learning take? Without disturbing comfort?
7. **Operation**: Does anyone need to know how it works? Repair (remotely)?
8. …what is missing?
9. **Profit**: How much? When?

# Breakout 2: NOTES

- **Straw-man building:** Building unrealistic. Only some buildings in this category have VAV.
  - How many categories? Decentralized RTUs on Box stores. Equipment from different eras
- **Constraints:** Yes, there is typically value in a smart system on a dumb building.
  - Prove payback in ~5 min of analysis with 10 Q/A (location, SF, retrofit, use, typical setpoints) and 2 yr of submeter data (don't need thermostat). >60% of US buildings have smart meters
- **Sale**: Facilities managers don't want this.
  - **Why?** Hassle of change, worry of reliability, more complicated maintenance, job security.
  - **Familiarity:** New "knobs" made to look familiar. Workforce must adapt to new systems. May not be able to repair complex controls like you'd repair a compressor.
  - **Other factors:** DG may drive up electricity prices ("death spiral") until we care about efficiency.
- **Design:** Piggyback on non-energy issue, such as cool design (Nest/Dyson) or **comfort-driven** retail sales (daylighting). Consumers and building owners will demand it, and facility managers follow suit.
  - < 20 sensors (depends on # of RTUs). Allow for occupant feedback. Occupancy measurements.
  - The biggest benefits can be obtained from scheduling, set points, economizing dampers, and demand-controlled ventilators. (Only possible if system has ventilation)
- **Installation:** Reduce risk, upfront costs. Cases when energy audits are not repeatable → lack of trust.
- **Operation:** You won't displace facilities managers until you can build system as smart as them (fixing system problems). Facilities managers may be willing to use a system that makes them more effective.
- **Incentivizing manufacturers:** Rooftop Challenge: Manufacturers like rewards for meeting specs.
- **Payback:** < 5 yr, underwriting possible

Breakout #3

# FUTURE R&D NEEDS

# Future R&D Needs

- **Objective**: Earlier we discussed the major one-off costs of deploying an energy saving building control system: design, tuning, equipment, etc.; and each of you have had recent breakthroughs in your lab. From here, what technological challenges can be overcome by future R&D efforts?

- **Questions**:
  - How do you determine if the system will actually save money?
  - Reliability: run well and that they can manage it
  - Technology metrics for success
  - Heilmeier questions

OPEN FLOOR

# WHAT ELSE IN THIS AREA SHOULD ARPA-E LOOK INTO?

# Breakout 3: NOTES

- Can get 80% of benefit from (1) scheduling, (2) set points, (3) economizer dampers, (4) demand controlled ventilators. Need to have communicating thermostats and communicating smart actuators.
- **Reliability:** communications (fault tolerant), data processing (outliers), event based v. sampled, 'limp-home' mode
  - **Metrics**: Comfort? Energy reliability? Down time?;
  - Market today is trained about broken stuff; Reliability of commissioning process
  - Error diagnoses and identification, and reporting to appropriate authority (service contracts)
- **Connectivity:**
  - **Architecture:** Distributed v decentralized ⇒ reliability vs performance (mode identification)
  - **'Last mile'**: WiFi persistence, ZigBee compatibility
- **Upgradability:** 'Self-healing' SW upgrades. Reconfigure based on changing energy prices. Modularity (backwards compatibility) . What are HW upgrade expectations? (Phones turn-over every 2 yr)
- **Standards:** Communications (backnet compliant). Can do it today, manually
  - Technology hurdles still to overcome. Switch gear from on- to off-grid – smart switching, reliability, protection
  - Interoperability of control and learning algorithms (SW-HW interface). Plug-n-play is mandatory
- **Pricing:** Real-time grid pricing integration
- **Features:** Need something that restarts, retunes, rebuilds
  - Need something that continually observe and adjusts – commissioning problems go away
  - Sensor/actuator discovery, type, capabilities, ID, and location
  - Fault detection
- **Market:** Barrier to market is user utility
- **Modeling**: Improving building models, including populating inputs and finding the most important parameters.
  - Utilization of design models for control, accounting for difference in model purpose.
  - Use the RAPMOD backpack to make the building model. Start with a questionnaire, need to automate the process of validation of an EnergyPlus model. ARPA-E hard is validation of the EnergyPlus model. Validation of the models is very important. Would need to walk around with the backpack once in a while.
  - Electrical load disaggregation would improve model