Enabling Energy Efficient Building Management Through Reduced CAPEX

ARPA-E Mini-workshop

October 23, 2014
DELTA
Delivering Efficient Local Thermal Amenities

FOA released 4/29/14; Concept Papers submitted 6/13/14
Hypothesis

- The latest breakthroughs in building controls have demonstrated significant efficiency improvements.
  - Experiments using model-predictive control have yielded energy reductions of 10 – 12% [Oldewurtel] and 60% [Bengea] over a baseline business as usual.

- Advanced energy saving building controls are costly to design, install, and tune for each one-off building.
  - Green premium ranges between 0% – 6.5% – 9%. [USGBC: 1,2,3]
  - Commissioning costs range from $0.30 to $2.50/ft² [Nicolow]

- Hindered adoption of these systems prevents energy savings nation-wide of greater than 1.0 quad per year.
  - Total US residential and commercial HVAC used ~9 quad in 2010
The Whitespace for Energy Saving Controls

![Diagram showing energy intensity and building size relationship with cost and commissioning fees.](image)

- **DRIVE DOWN COSTS**
- **Increasing complexity**
- **Spreading Costs**
- **Low-cost Smart thermostat**
- **Economical BM & BMS**

**Building Size (thousand sf)**

**Sources:**
- EIA Building Energy Data Book
- RSMeans Online
- LBL Report

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October 23, 2014

Enabling Energy Efficient Building Management - ARPA-E Mini-workshop
Outline

- Workshop objectives
- US building energy consumption
- Current trends in building energy efficiency
- The challenge of mid-sized buildings
- Enabling technologies
- Workshop objectives reminder
- Workshop agenda
Outline

‣ Workshop objectives

‣ US building energy consumption

‣ Current trends in building energy efficiency

‣ The challenge of mid-sized buildings

‣ Enabling technologies

‣ Workshop objectives reminder

‣ Workshop agenda
Workshop Objectives

‣ **Define opportunities**: Break down the major costs to implementing energy saving building controls.

‣ **Identify technologies**: What technological approaches will be able to drive down each of the major costs?

‣ **Define metrics**: What are the cost and performance metrics that will inspire widespread adoption?
Outline

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US Energy Consumption

HIGH BUILDING ENERGY USAGE

“[New smart building systems] will save 10-plus percent of the energy, and then after 20 years, it’s out of tune, you can re-tune it up and you will save a tremendous amount of energy...We design airplanes in such a way, we can design buildings in that way too.” (Chu 2011)
US Energy Consumption

IN-EFFICIENT LEGACY BUILDING STOCK

Figure 6. About half of all commercial buildings were constructed before 1980

LESS THAN 2% INDUSTRY R&D SPENDING
Outline

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Who is doing What?

- **Who:** building type
  - % of respondents to EEVS / Bloomberg Energy Efficiency Trends surveys.

- **What:** type of EE projects
  - % of respondents to EEVS / Bloomberg Energy Efficiency Trends surveys.

```
<table>
<thead>
<tr>
<th>Building Type</th>
<th>% of Respondents</th>
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<tbody>
<tr>
<td>Office</td>
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<tr>
<td>Public Building</td>
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<tr>
<td>School</td>
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<td>University</td>
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<td>Manufacturing</td>
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<td>Leisure Centre / Sports</td>
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<td>Residential</td>
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<tr>
<td>Other</td>
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<tr>
<td>Hotel</td>
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<tr>
<td>Hospital</td>
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</tr>
<tr>
<td>Warehousing &amp; Distribution</td>
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<tr>
<td>Laboratory</td>
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<tr>
<td>Data Centre</td>
<td></td>
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<tr>
<td>Restaurant &amp; Bars</td>
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<tr>
<td>Retail - High Street</td>
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<tr>
<td>Retail - Out of Town</td>
<td></td>
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<tr>
<td>Retail - Supermarket</td>
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</tr>
</tbody>
</table>

- **Other**

```

- **Other Energy Efficiency Projects**
  - Lighting - High Efficiency
  - Lighting - Controls
  - Behaviour Change
  - Building Energy Management System
  - Boiler - Controls
  - Power Management - VO, PFC
  - Boiler - High Efficiency Unit
  - Building Fabric - Glazing, Insulation, Materials
  - Boiler - Optimisation
  - Motors & Drives
  - Solar - Photovoltaic
  - Cooling & Air Conditioning
  - High Speed Hand Dryers
  - HVAC
  - Heat Exchangers
  - Combined Heat & Power
  - Energy Recovery
  - Solar - Thermal
  - Compressed Air Equipment
  - Heat Pump - Air Source
  - Refrigeration - Controls
  - Refrigeration - High Efficiency Unit
  - Refrigeration - Optimisation
  - Heat Pumps - Ground Source
  - Radiant & Warm Air Heaters
  - Other

October 23, 2014

Enabling Energy Efficient Building Management - ARPA-E Mini-workshop
Retro-commissioning

**Compares Performance**

![Energy Cost Savings Chart]

**Prevent/ID Degradation**

![Test Envelope Image]

**Tune BMS**

![BMS Tuning Image]

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[www.horizon-engineering.com](http://www.horizon-engineering.com)
[www.glumac.com](http://www.glumac.com)
[www.lbl.gov](http://www.lbl.gov)
[www.myhvacperformance.com](http://www.myhvacperformance.com)
Microsoft’s Smart Campus

“Our smart buildings work serves up data for me in easily consumable formats so now I get to spend 95% of my time doing engineering, which is great.”

- Jonathan Corr, Bing BNI

125 buildings with...
2,000,000 data points

500,000,000 data transactions every 24 hours

Communicated through an array of different Protocols, Hardware, and Interfaces

Make your building smarter.

Optimize. Continuously.

The BrightBox Difference - Real Data

<table>
<thead>
<tr>
<th>Solution</th>
<th>Impact</th>
<th>BrightBox</th>
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<tr>
<td>Solution3</td>
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</tbody>
</table>
Smart Thermostats

Cost of Selected Thermostats

- Nest: $249
- Honeywell: $249
- ecobee: $299
- ecobee3: $244
Smart Thermostats

Estimated Payback Period

Connection point with the rest of the smart home

1.4 yrs

1.4 yrs

1.7 yrs

1.4 yrs
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DRIVE DOWN COSTS

Modeling, Design, Commissioning Fees ($/sf)

Building Size (thousand sf)

Low-cost Smart thermostat

Economical BM & BMS

Increasing complexity

Spreading Costs

EIA Building Energy Data Book, RSMeans Online, LBL Report
## HVAC Energy Usage

<table>
<thead>
<tr>
<th>Principal Building Activity</th>
<th>HVAC Energy (Trillion BTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Building Size</td>
</tr>
<tr>
<td></td>
<td>1,001 to 5,000 Square Feet</td>
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<tr>
<td>Education</td>
<td>27 23 59 100 16 3 134 98 346</td>
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<tr>
<td>Office</td>
<td>71 45 95 76 60 77 82 47 275</td>
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<tr>
<td>Public Assembly</td>
<td>27 38 91 25 39 68 193</td>
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<td>Warehouse and Storage</td>
<td>20 19 51 23 36 27 32 129</td>
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<td>Service</td>
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<tr>
<td>Religious Worship</td>
<td>14 24 44 31 &gt; 99</td>
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<tr>
<td>Retail (Other Than Mall)</td>
<td>25 25 50 18 21 &gt; 93</td>
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<tr>
<td>Lodging</td>
<td>3 5 20 26 25 31 42 75</td>
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<tr>
<td>Food Service</td>
<td>46 37 30 &gt; 67</td>
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<td>Inpatient</td>
<td>8 14 16 11 41</td>
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<tr>
<td>Outpatient</td>
<td>91 65 &gt; 0</td>
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<tr>
<td>Public Order and Safety</td>
<td>8 &gt; 0</td>
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<tr>
<td>Other</td>
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</table>

Notes:
- HVAC Energy (Trillion BTU)
## HVAC Energy Usage

<table>
<thead>
<tr>
<th>Principal Building Activity</th>
<th>5,001 to 10,000 Square Feet</th>
<th>10,001 to 25,000 Square Feet</th>
<th>25,001 to 50,000 Square Feet</th>
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### HVAC Energy (Trillion BTU)

- **1.00 quad** (commercial) + **0.25 quad** (multi-family res.)
- **~1.25 quad** Mid-sized HVAC
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Federal Research Dollars...

A low cost, wireless "peel and stick" sensor

**Opportunity:** Cheap and wireless sensors will enable enhanced building controls; requirement for future transaction platform

**Problem:** Communicating sensors are too expensive

**Solution:** Low cost, wireless sensors that are fully printable "peel and stick" and cost $1-$10/node vs. $150-$300/node

**FY13 goals (metrics):** Prototype multi-sensor platform

- Comprised of new high performance materials using a unique low temperature thin film integration platform
- Performance specifications:
  - Transmission rate: every 80 seconds
  - Power harvesting from ambient light
  - Parameters measured: Temperature, humidity, light intensity
  - Range: 50 feet (tested), expected range (2K-3K feet)
  - RF frequency: 315 MHz

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**Models, Tools, and Information Resources**

**Data-driven Decision Making**

**Opportunity**

Communicate the value of energy efficiency to encourage adoption of technologies (lower the risk).

**Strategy**

- Inform users about their energy use and ways to reduce it.
- Enable comparison of energy efficiency opportunities.
- Educate building science professionals.

**Recent Accomplishments & Impacts**

- THOUSANDS of building datasets
- OVER 1,250,000 building energy model and software users
- 10+ tools
- HUNDREDS of innovations proven by experts
- OVER 500 case studies and reports

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**What do we do with all the sensors & platforms?**
You All!

**Data Fusion + Mining**
- lutron.com
- flir.com
- flickr.com/ursonate
- Borrelli (Berkeley)

**Model Synthesis**
- synsys.com

**UI / UX**
- wikipedia.com
- nest.com

**Advanced Controls and HVAC Architectures**
- mopawett.com

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October 23, 2014
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**Workshop agenda**
<table>
<thead>
<tr>
<th>Time</th>
<th>Duration</th>
<th>Session Description</th>
<th>Presenter(s)</th>
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<tbody>
<tr>
<td>8:45AM</td>
<td>30m</td>
<td>Registration &amp; Breakfast</td>
<td></td>
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<tr>
<td>9:15AM</td>
<td>15m</td>
<td>Welcome &amp; Introduction to ARPA-E</td>
<td>Eric Rohlfing (ARPA-E)</td>
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<tr>
<td>9:30AM</td>
<td>30m</td>
<td>Introduction to workshop</td>
<td>Mike Kane (ARPA-E)</td>
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<tr>
<td>10:00AM</td>
<td>45m</td>
<td>Lightning Introductions</td>
<td>All</td>
</tr>
<tr>
<td>10:45AM</td>
<td>15m</td>
<td>Coffee break</td>
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<tr>
<td>11:00AM</td>
<td>15m</td>
<td>Novel modeling and controls of buildings</td>
<td>Igor Mezic (UCSB)</td>
</tr>
<tr>
<td>11:15AM</td>
<td>15m</td>
<td>Breakthroughs in sensing and data systems</td>
<td>Sidhant Gupta (Microsoft)</td>
</tr>
<tr>
<td>11:30AM</td>
<td>15m</td>
<td>Implementation considerations presentation</td>
<td>Jon Judkoff (NREL)</td>
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<tr>
<td>11:45AM</td>
<td>45m</td>
<td>12:30PM Breakout #1: Defining the opportunity</td>
<td>SEE GROUPS</td>
</tr>
<tr>
<td>12:30PM</td>
<td>45m</td>
<td>1:15PM Lunch</td>
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<tr>
<td>1:15PM</td>
<td>15m</td>
<td>1:30PM Breakout #1: Readout</td>
<td>Note takers</td>
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<tr>
<td>1:30PM</td>
<td>60m</td>
<td>2:30PM Breakout #2: The straw-man</td>
<td>SEE GROUPS</td>
</tr>
<tr>
<td>2:30PM</td>
<td>15m</td>
<td>2:45PM Recess</td>
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<tr>
<td>2:45PM</td>
<td>60m</td>
<td>3:45PM Breakout #3: Future R&amp;D</td>
<td>SEE GROUPS</td>
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<tr>
<td>3:45PM</td>
<td>30m</td>
<td>4:15PM Readouts from breakouts</td>
<td>Note takers</td>
</tr>
<tr>
<td>4:15PM</td>
<td>30m</td>
<td>4:45PM Open floor and wrap-up</td>
<td>Mike Kane (ARPA-E)</td>
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</tbody>
</table>