# Pre-Commercial Demonstration of Cost-Effective Advanced HVAC Controls

2014 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

**Hayden Reeve, reevehm@utrc.utc.com**
**United Technologies Research Center**

# Project Summary

**Timeline:**

Start date: Feb 1, 2011

Planned end date: April 30, 2015

Key Milestones

1. Model eval. of opt. control benefits (01/13)
2. Demonstration of opt. control in two buildings (9/13 and 1/14)
3. Demonstration of scalable deployment in two buildings (2/15)

**Key Partners:**

| | |
|---|---|
| Penn State | Virginia Tech |
| Purdue | UTC |
| | |
| | |
| | |

**Budget:**

Total DOE $ to date: $0.86M (through 3/2014)

Total Cost Share $ to date: $0.43M

Total future DOE $: $0.45M (4/2014-3/2015)

Total future Cost Share $: $0.11M

**Project Goal:**

**Demonstrate cost-effective and scalable deployment of optimal controls** that achieve >20% HVAC energy reduction versus state-of-the-art building automation systems.

**Target Market/Audience:**

This technology targets building automation systems for medium-size buildings with central HVAC systems. Medium and large market segments account for ~35% of commercial building HVAC energy use (1.9 Quads).

# Purpose and Objectives

**Problem Statement**: Optimal control coordination of HVAC equipment can reduce energy by >20% over current building automation systems (BAS) but is not widely deployed due to **challenges with complexity, scalability, and deployment.**

**Target Market and Audience**: This technology targets building automation systems (BAS) for medium buildings with central HVAC systems. These systems account for ~35% of commercial building HVAC energy use (1.9 Quads).

**Impact of Project**: Provide a proof-point of commercial viability through demonstration of **cost-effective deployment** of optimal building controls:

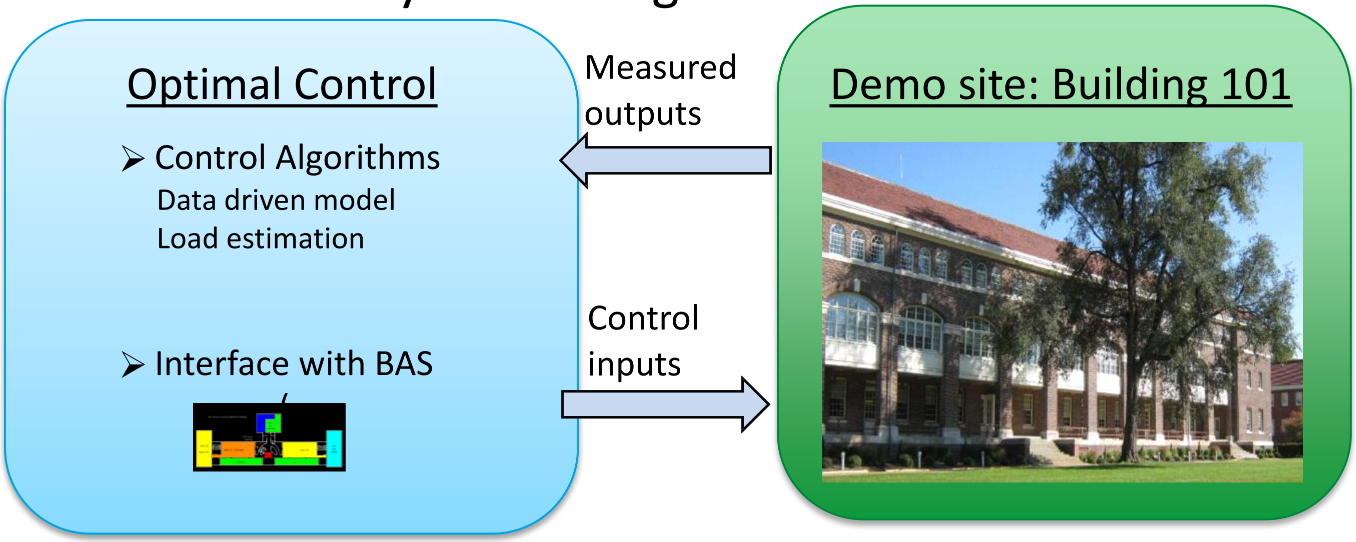
1. Near-term: successful demonstration of scalable and cost effective (<3 year payback) optimal controls that reduces HVAC energy usage by >20% over current BAS control
2. Intermediate-term: accelerated commercialization of technology
3. Long-term: Wide-spread scalable deployment of adaptive optimal controls that achieve >20% HVAC energy reduction.

# Approach

**Approach**: Demonstrate benefits of optimal HVAC equipment operation in real buildings versus current BAS control.

**Key Issues**: Cost-effective, scalable deployment requires adaptive optimal control approach compatible with current BAS architectures and the skillset of field personnel.

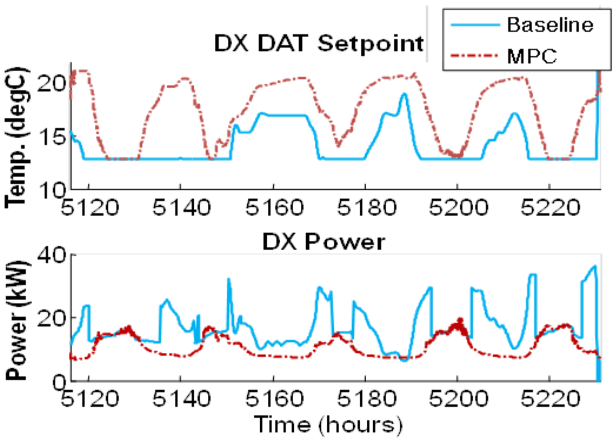
**Distinctive Characteristics**: Requires no building specific models, no manual calibration, and uses existing BAS hardware and sensors.  Can be offered as retro-fit overlay to existing BAS.



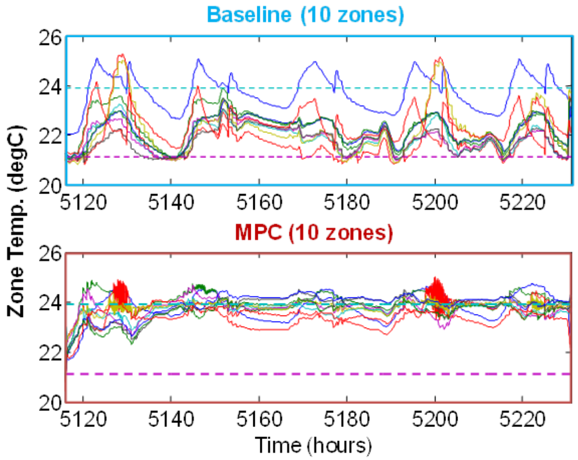
# Results: Building 101 – The Navy Yard, Philadelphia

## Predicted Energy Savings

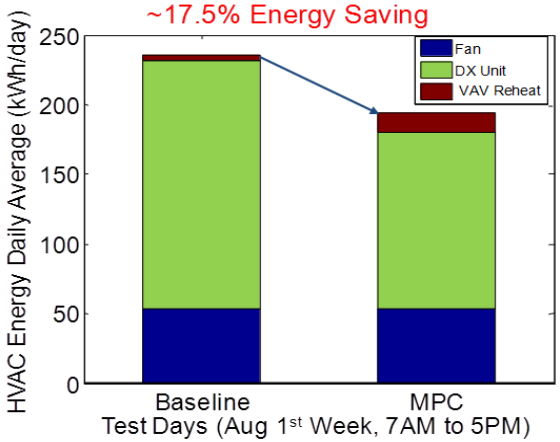
Equipment Optimization




Superior Comfort




Reduced Energy Usage




**Model-based evaluation enables investigation of season, climate zone, and building type impact on energy savings.**

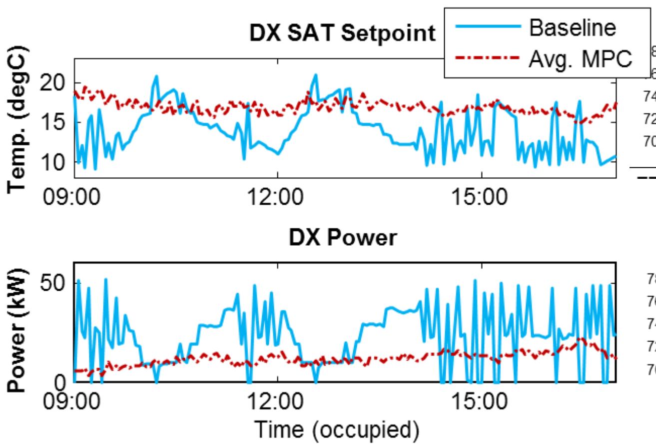
**~20% HVAC energy reduction predicted for Bldg. 101**

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

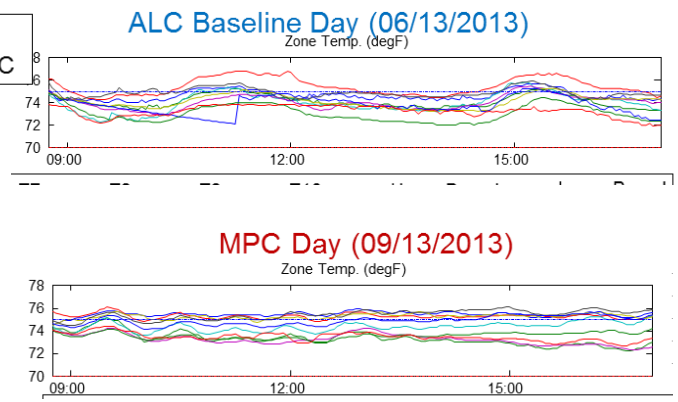
# Results: Building 101 – The Navy Yard, Philadelphia

## Building Demonstration Results

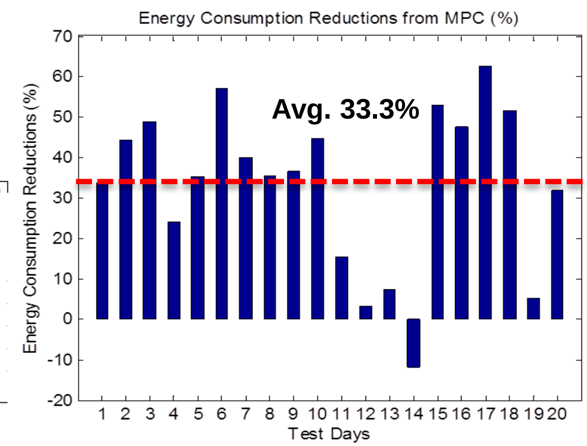
Equipment Optimization




Superior Comfort




Reduced Energy Usage



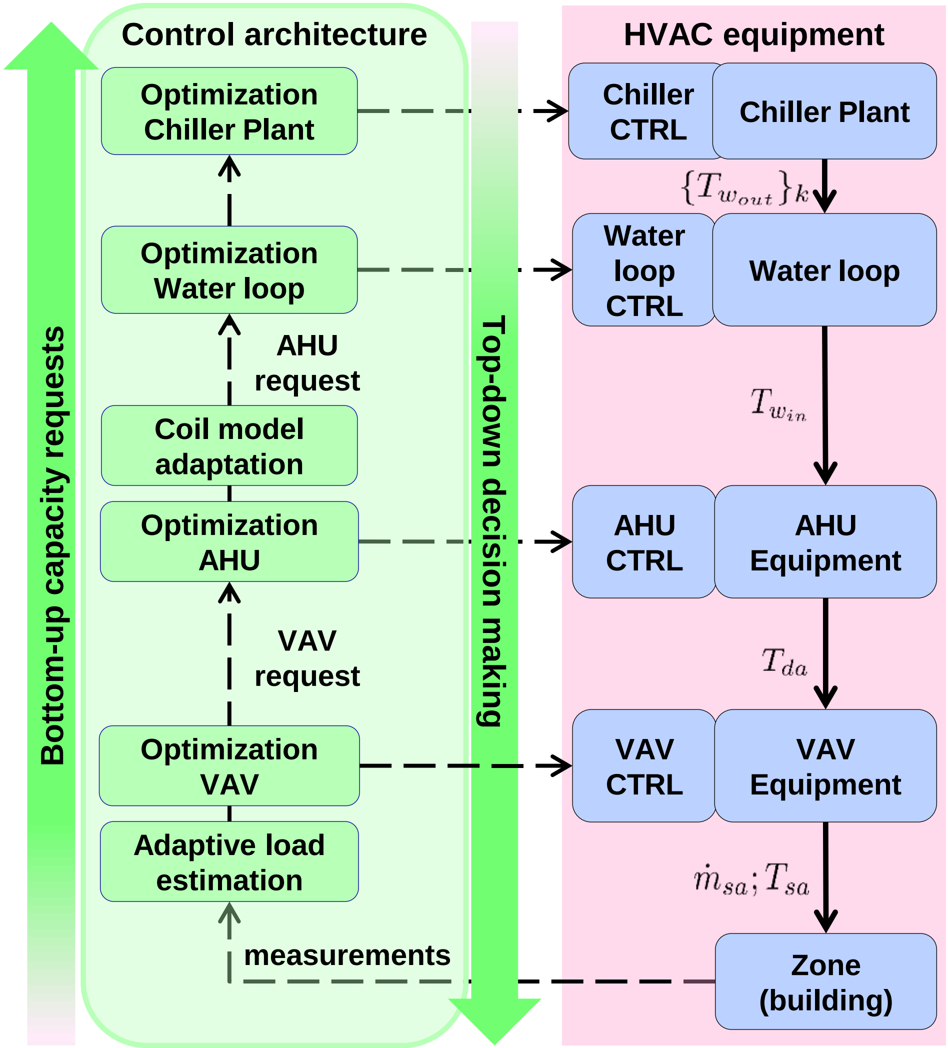

**Real-world demonstration validates approach and provides proof-point to stakeholders.**

**>20% HVAC energy reduction demonstrated in Bldg. 101**



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Scalable Deployment: Distributed Opt. Approach




- Scalable: Approach mirrors current control architecture and hardware structure
- Deployable: Adaptive self-deployed online estimation models eliminate the need for manual model calibration and (re)tuning

# Progress and Accomplishments

**Lessons Learned**:

1) Focus on installation cost and complexity should be commensurate with focus on energy savings. Leveraging lessons learned and conclusions from previous DOE and DOD efforts.
2) Demonstrating benefits in field requires careful back-to-back comparison (accounting for weather, occupancy etc.)
3) Healthy building equipment is pre-requisite for optimal operation.

**Accomplishments**: Demonstrated >20% HVAC energy reduction versus current BAS control while reducing discomfort and equipment cycling.

**Market Impact**: Demonstrated >20% HVAC energy reduction beyond current BAS control (with existing hardware and sensors) consistent with project goals. Will demonstrate scalable approach can meet deployment requirements:

1. Define requirements for commercially viable deployment
2. Demonstrate that adaptive optimal approaches can meet these requirements

**Awards/Recognition**: None

# Project Integration and Collaboration

**Project Integration**: Engaged industry (Automated Logic Corporation) and academia (VT, Purdue, etc) to review technical approach and market requirements.

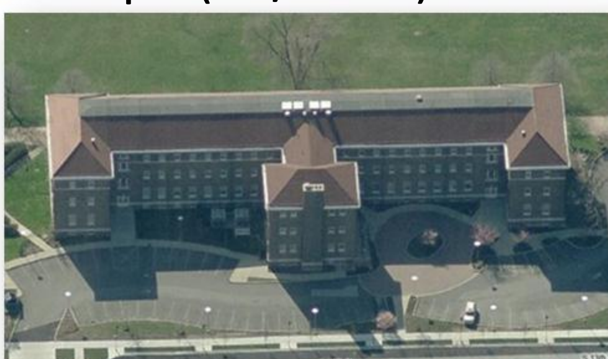
**Partners, Subcontractors, and Collaborators**: This work is undertaken as part of the Penn State Consortium for Building Energy Innovation (CBEI), formerly the Energy Efficient Building Hub. Overall controls team under this consortium includes Penn State (Stephen Treado), Purdue (Jim Braun), and VT (Eugene Cliff).

**Communications**: Work profiled at DOE Controls Workshop (2013, Portland), International High Performance Buildings Conference (2013-2014, Purdue), Intelligent Buildings Operations Workshop (2013, UC-Boulder), and Engineered Systems HPB Conference (2012, VA).

# Next Steps and Future Plans

**Next Steps and Future Plans**: Demonstrate scalable installation of optimal controls in two buildings by February 2015:

1. Document installation effort and resulting performance at Bldg. 101 (7/2014)
2. Go/No-Go: Installation effort demonstrates path to meet commercialization requirements (10/2014)
3. Implement diagnostics at 2nd demo site (Swope) to ensure system health (10/2014)
4. Document installation effort and resulting benefits of optimal controls at Swope (01/2015)



Bldg. 101: Philadelphia Navy Yard

Swope School of Music, West Chester, PA

# REFERENCE SLIDES

# Project Budget

**Project Budget**: Annually funded as part of CBEI. Total DOE budget $1.32M.
**Variances**: No project budget variances to date. 2013 demonstration plan modified to address building HVAC equipment failures (DX replacement) and Swope building demonstration delay.
**Cost to Date**: $860K (65%) of DOE funds expended to date
**Additional Funding**: Cost share (UTC): $430K to date; additional $112K planned.

| Budget History | | | | | |
|---|---|---|---|---|---|
| 02/2011– FY2013 (past) | | FY2014 (current) | | FY2015 – 04/2015 (planned) | |
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| $756K | $378K | $553K | $164K | - | - |

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Project Plan and Schedule

- 2013 demonstration plans redirected due to building equipment failures. Swope demonstration to be completed in 2014.
- Budget Period 4 effort to start 05/2014.
- Go/No-Go: Show path to scalable and cost effective deployment (10/2014)