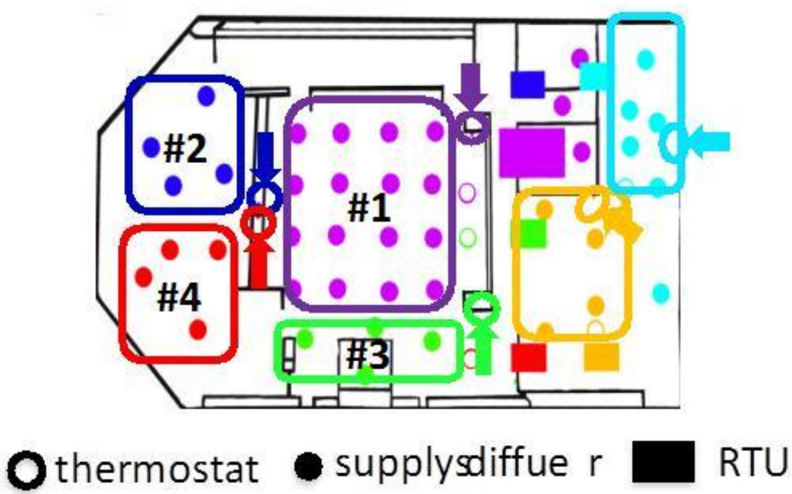
CBEI - Coordinating RTUs in Small & Medium Sized Commercial Buildings

2015 Building Technologies Office Peer Review



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Project Summary

Timeline:

Start date: 5/1/2014

Planned end date: 4/30/2016

Key Milestones

1. Adaptive control modeling, 10/15/14
2. Energy savings assessments, 2/28/15

Budget:

Total DOE $ to date: **$350,000**

Total future DOE $: **$200,000**

Target Market/Audience:

Small and medium-size commercial buildings (SMSCBs) served by RTUs

Key Partners:

CBEI - Purdue
CBEI - Virginia Tech
Oak Ridge National Lab
Field Diagnostics Services, Inc.
FrontStreet Facilities Solution

Project Goals:

1. Develop, demonstrate, and evaluate an rooftop unit (RTU) coordinator that: a) minimizes energy consumption & peak demand; 2) does not require additional sensors; 3) requires minimal implementation expertise
2. Further develop simulation tool that can be used as a testbed for evaluating control approaches in open spaces served by RTUs

CONSORTIUM for BUILDING ENERGY INNOVATION

Vision:

By 2030, deep energy retro-fits that reduce energy use by 50% in existing SMSCB, which are less than 250,000 sq ft

Mission:

Develop, demonstrate and deploy technology systems and market pathways that permit early progress (20-30% energy use reductions) in Small and Medium Sized Commercial Buildings

Our Goals:

- **Enable deep energy retrofits** in small to medium sized commercial buildings
- **Demonstrate energy efficient systems** tailored for SMSCBs in occupied buildings – living labs
- **Develop effective market pathways** for energy efficiency with utilities and other commercial stakeholders: brokers, finance, service providers.
- **Provide analytical tools** to link state and local policies with utility efficiency programs

CBEI Partners

Industry

Bayer MaterialScience

United Technologies Research Center

Economic Development Organizations

DVIRC

PIDC – Driving growth to every corner of Philadelphia

Ben Franklin Technology PArtners

Universities

PennState

NJIT

Penn – University of Pennsylvania

Drexel University

Carnegie Mellon University

VirginiaTech – Invent the Future

Purdue University

Morgan State University – Gateway to Opportunity, Stairway to Excellence

Rutgers

Purpose and Objectives

Problem Statement: Advanced controls for SMSCBs (small and medium-size commercial buildings) are rarely implemented because of poor overall economics. Low-touch, low-cost control implementations are needed.

Target Market and Audience:

- Market is SMCBs that utilize RTUs for cooling.
- RTUs serve about 60% of commercial floor space & account for ~150 TWh of annual electrical usage (~1.56 Quads primary energy for cooling) & ~$15B in electric bills.
- Audience is companies that can build successful businesses to deliver advanced RTU controls for SMSCBs.

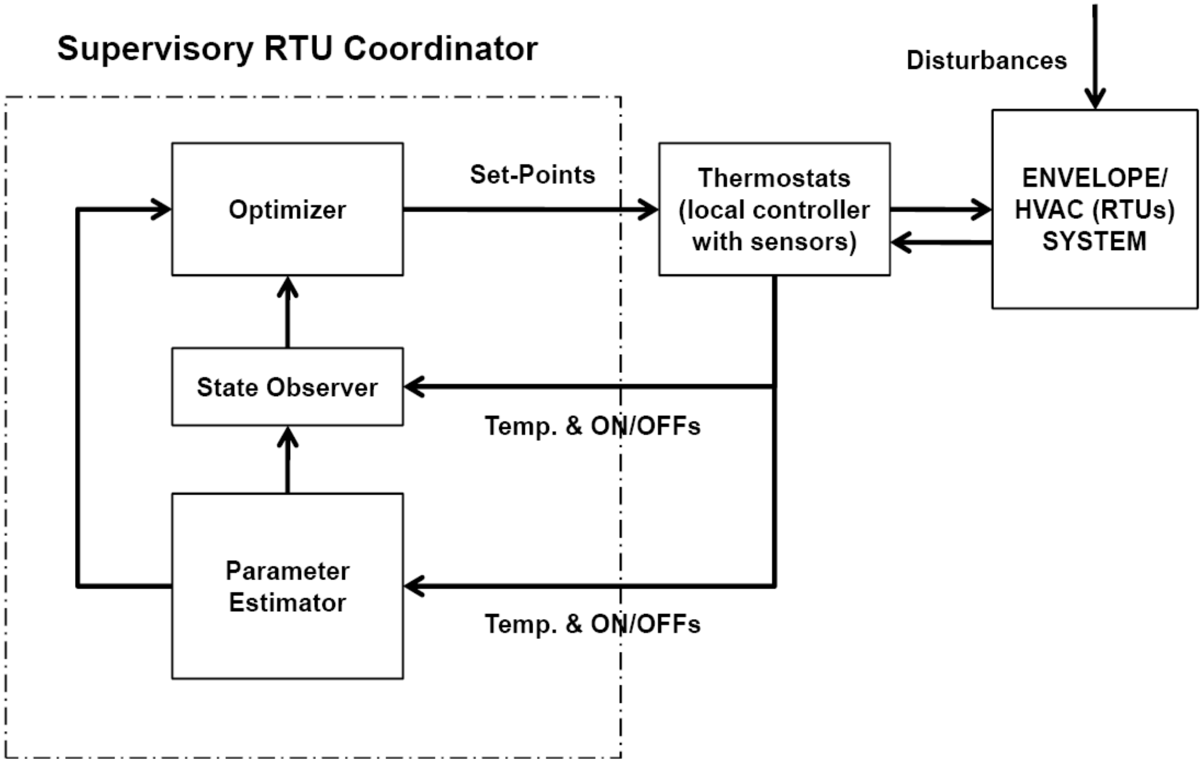
Purpose and Objectives

Impact of Project:

- General algorithm to enable "Plug-and-Play" (PnP RTU) Coordinator → interface to thermostat; no additional measurements; adaptively learns behavior
- Variety of possible commercial implementations
  - cloud-based using web-enabled thermostats
  - low-cost RTU coordination control hardware
  - software overlay on top of existing (energy management system) EMS for enterprise solutions
  - implementation as a standard application within EMS
  - embedded in smart RTU controllers
- Demonstrating cost savings and different implementation approaches in collaboration with commercial partners
  - Energy savings potential of > 20 TWh electricity (~0.25 Quad primary) per year
  - Utility cost savings potential > $2B per year
  - Minimal implementation costs once infrastructure is in place (e.g., communicating thermostats and cloud-based infrastructure or low-cost hardware/software for stand-alone setup at the site)

Approach – RTU Coordinator Algorithm

- Learns relationship between thermostat temperatures and RTU on/off staging (no other measurements required)
- Determines RTU staging to minimize energy (based on RTU rated power or measurements if available)



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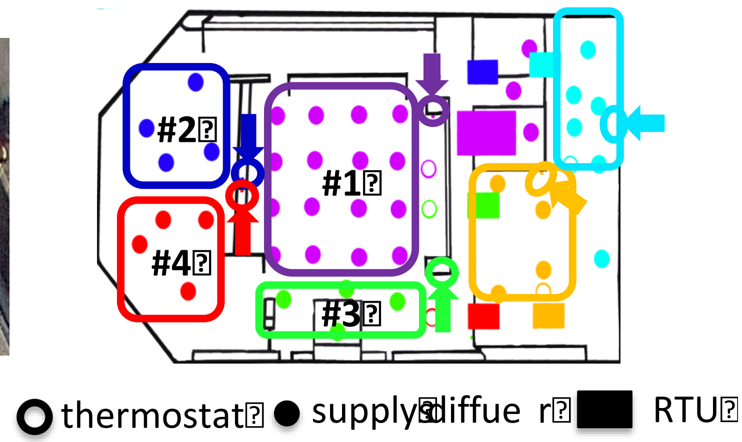
Approach – RTU Coordinator Evaluation

- Short-term field testing for controller evaluation & virtual testbed validation
- Virtual testbed simulation for 3-month comparison of controllers for identical weather and occupancy schedules: not possible at field sites

Central Baptist Church (CBC), Knoxville, TN

Harvest Grill (HG) Restaurant, Glenn Mills, PA



- **HG Dining Area**: 4 RTUs, RTU1 has 2 stages with 3 times capacity and 35% greater efficiency than other RTUs
- **CBC** has 4, 2-stage identical RTUs

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Approach – Virtual Testbed

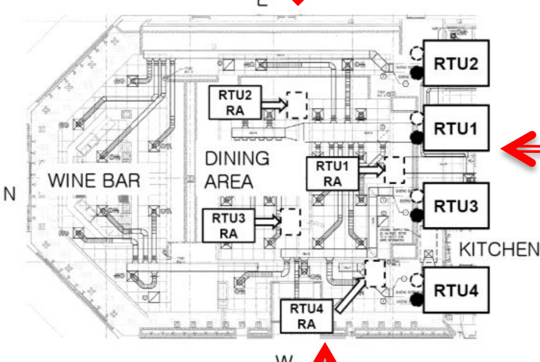
Simulation test bed

RTU coordinator

Thermostat signals

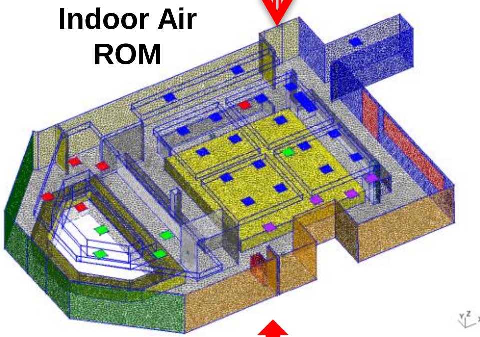
Weather

Envelope Model



Equipments

Indoor Air ROM



Internal gain

"fast" reduced-order models that couple building envelope & indoor air dynamics

Approach and Accomplishments

Key Issues: 1) refining adaptive modeling approach for controller; 2) demonstrating cost savings potential; 3) developing alternative implementation approaches and demonstrating requirements

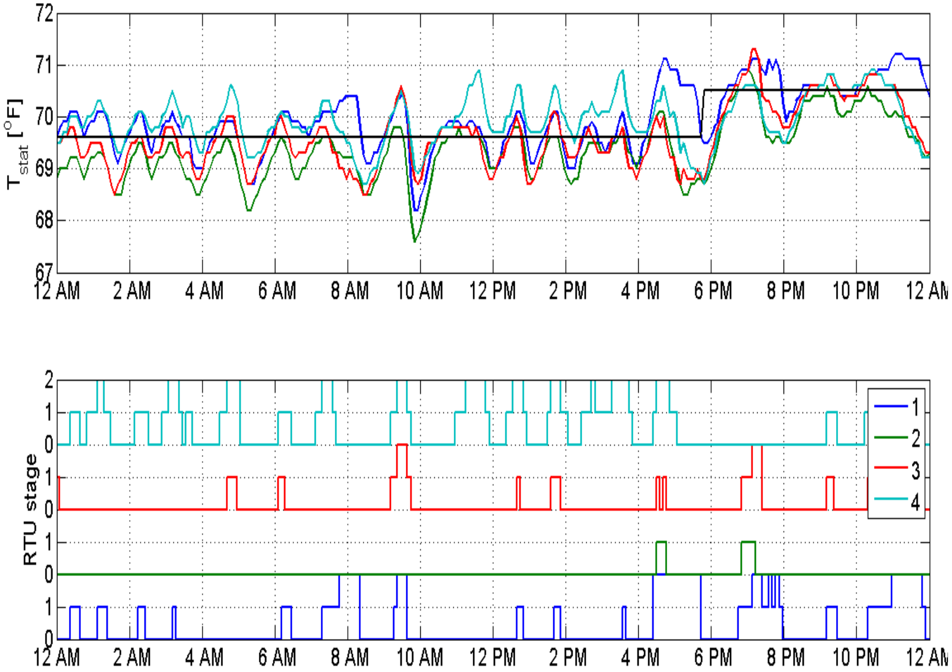
Distinctive Characteristics: 1) Energy efficient control with minimal sensors, set-up & infrastructure; 2) Unique simulation platform for assessing long-term RTU coordination control performance

Summary of Accomplishments:

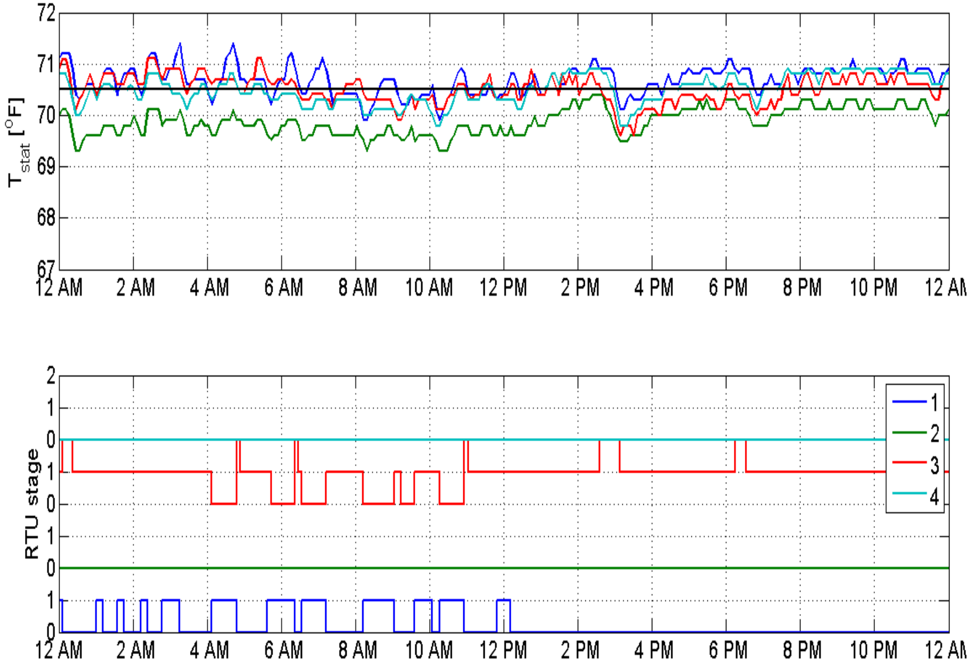
- Validation of virtual testbed at two sites
- Validation/demonstration of significant energy (e.g., 20%) and peak demand (e.g., 30%) savings
- Demonstration of alternative implementation platforms
- Developed relationships with commercial partners and customers for additional development and demonstration

Accomplishments - Short-Term Field Tests for CBC

Conventional



PnP RTU Coordinator



Conventional

- High peak demand
- Significant short cycling of equipment

Plug-n-Play (PnP)

- Utilizes RTU_1 and RTU_3 as much as possible; See T_2 and T_4 while corresponding RTUs are off.)
- Reduces short cycling with better comfort
- Significant peak demand reduction

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Accomplishments – 1-Week Field Tests for CBC

Energy and Demand Savings

	% Energy Savings	Peak Demand Reduction (15 min moving average)
PnP	8.23	42.57

Comfort Comparisons

	Conv	PnP
Max. Comfort violation	2.5ºF	1.2ºF

Notes

- Relatively small energy savings because units are identical → primary savings due to reduced cycling
- Large demand savings → units are oversized, zones served by RTUs are closely coupled, week test period doesn't contain the summer peaks
- Testing at field site limited to one week period with day-to-day alternating control approaches→ need for longer term assessments

Accomplishments – Simulated Summer Results for CBC

	June		July		August		3-Month Totals	
	Conv	PnP	Conv	PnP	Conv	PnP	Conv	PnP
Energy (MWh)	5.9	5.5	7.8	7.1	5.5	4.8	19.2	17.4
Energy Cost ($)	588.3	546.5	780.0	714.0	553.1	475.8	1921.4	1736.3
Peak Power (kW)	37.9	27.8	42.3	35.9	39.5	27.7	-	-
Demand Charge ($)	454.7	333.8	507.6	430.3	473.7	332.4	1435.9	1096.5
Total Cost ($)	1043.0	880.3	1287.6	1144.3	1026.8	808.2	3357.3	2832.8
Cost Savings ($)		162.7		143.3		218.5		524.5
Cost Savings (%)		15.6		11.1		21.3		15.6
Energy Savings (%)		7.1		8.5		14.0		9.6
Peak Demand Cost Reduction (%)		26.6		15.2		29.8		23.6

Notes

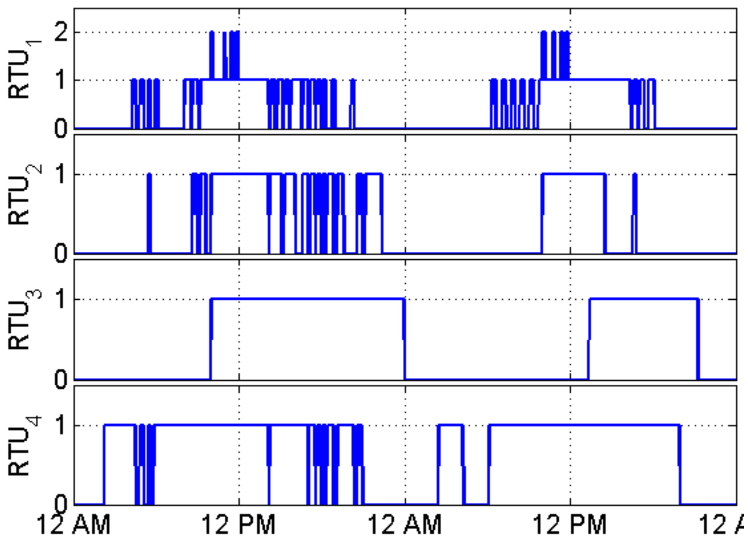
- Relatively low energy savings because RTUs are identical
- Large demand savings peak even in peak summer month because of unit oversizing

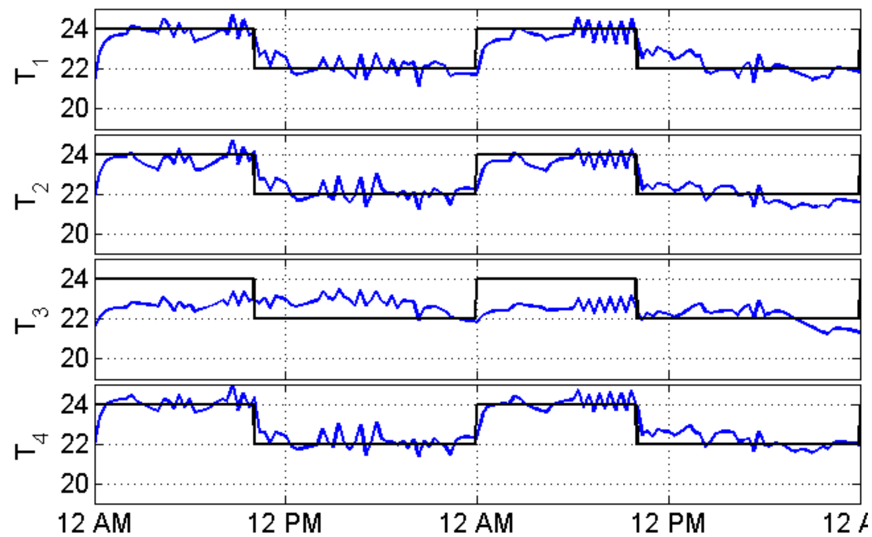
Accomplishments – Simulated Short-term Results for HG

RTU Staging

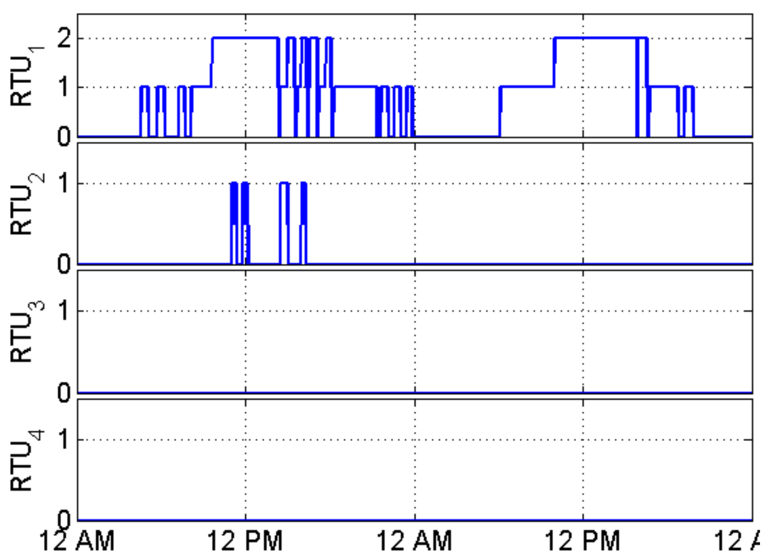
Thermostat Temperature Profiles

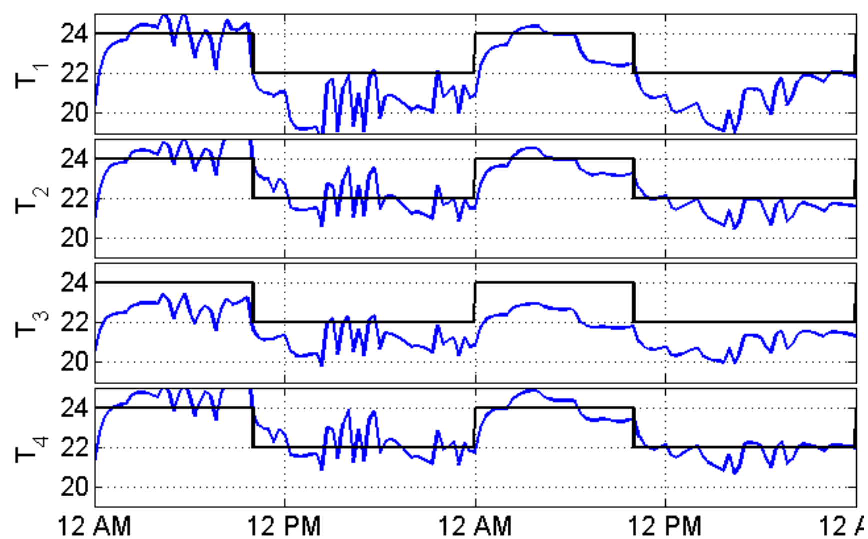
Conv





PnP





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Accomplishments – Simulated Summer Results for HG

	June		July		August		3-Month Totals	
	Conv	PnP	Conv	PnP	Conv	PnP	Conv	PnP
Energy (MWh)	6.7	5.2	8.2	6.1	7.4	5.5	22.3	16.9
Energy Cost ($)	669.2	523.6	820.5	614.5	737.1	554.3	2226.8	1692.4
Peak Power (kW)	30.0	20.7	30.3	21.1	30.6	30.0	-	-
Demand Charge ($)	360.4	248.6	364.2	252.8	366.8	359.9	1091.4	861.2
Total Cost ($)	1029.6	772.2	1184.7	867.3	1103.9	914.1	3318.1	2553.6
Cost Savings ($)		257.3		317.4		189.7		764.5
Cost Savings (%)		25.0		26.8		17.2		23.0
Energy Savings (%)		21.8		25.1		24.8		24.0
Peak Demand Cost Reduction (%)		31.0		30.6		1.9		21.1

Notes

- Significant energy savings due to greater operation of more efficient RTU1
- Significant demand savings except in month having peak cooling (Aug)

Progress and Accomplishments

Market Impact: Have established collaborations with commercial partners and their end-use customers to further develop implementation paths and set up additional demonstrations. Working with:

- Field Diagnostics Services, Inc. (FDSI) to set up enterprise solution for Bank of America using existing EMS infrastructure
- FDSI to set up and demonstrate cloud-based solution using web-enabled thermostats
- FrontStreet Facilities Solution to set up and demonstrate cloud-based solution for a national retail account

Project Integration and Collaboration

Project Integration: Closely working with commercial collaborators to further market demonstration and deployment

Partners, Subcontractors, and Collaborators: Purdue is responsible for algorithm development and evaluation; Virginia Tech is developing reduced-order indoor air modeling; ORNL provided access and support for field site demonstrations and assessments; FDSI and FrontStreet are working with end-use customers to establish implementation requirements and set up future demonstrations

Communications: The RTU Coordinator was presented in a seminar at the ASHRAE Winter Meeting, 2015.

Next Steps and Future Plans

Next Steps and Future Plans:

- Demonstrate cloud-based implementation requirements and savings opportunities for a retail store managed by FrontStreet Facilities Solution
- Demonstrate enterprise solution with FDSI for Bank of America (BOA) using existing EMS infrastructure

REFERENCE SLIDES

Project Budget

Project Budget: $350,000
Variances: None
Cost to Date: $350,000

Budget History					
CBEI BP3 (past) 2/1/2013 – 4/30/2014		CBEI BP4 (current) 5/1/2014 – 4/30/2015		CBEI BP5 (planned) 5/1/2015 – 4/30/2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		$350,000	$22,000	$200,000	$22,000

CBEI – Consortium for Building Energy Innovation (formerly EEB Hub)
BP – Budget Period

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Project Plan and Schedule

- Go/No-Gos completed on October 20, 2014 and February 28, 2015

Project Schedule												
Project Start: **5/1/2014**		Completed Work										
Projected End: **4/30/2016**		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned) use for missed milestones										
		Milestone/Deliverable (Actual) use when met on time										
	BP3 (2013-14)				BP4 (2014-15)				CBEI BP5 (2015-16)			
Task	Q1 (Feb-Apr)	Q2 (May-Jul)	Q3 (Aug-Oct)	Q4 (Nov-Apr)	Q1 (May-Jul)	Q2 (Aug-Oct)	Q3 (Nov-Jan)	Q4 (Feb-Apr)	Q1 (May-Jul)	Q2 (Aug-Oct)	Q3 (Nov-Jan)	Q4 (Feb-Apr)
Past Work												
Model and Control Development												
Control and Testbed Assessments												
Cooling -Side Load Meter Evaluation												
Current/Future Work												
Tools & Processes for Prioritizing Sites												
Prioritize Bank of America Sites												
Deploy RTU Coordinator at Pilot Sites												
Assess Performance												

BP – Budget Period for Consortium for Building Energy Innovation (formerly EEB Hub)