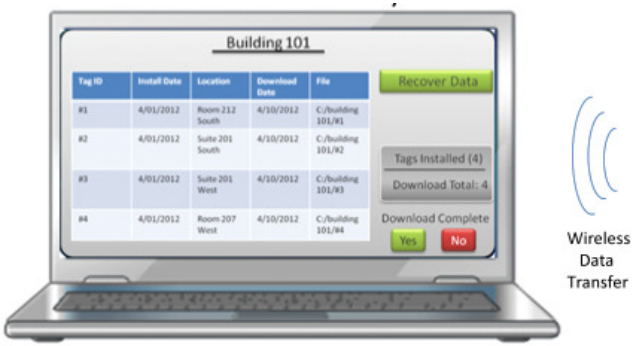
Retro-commissioning Sensor Suitcase Technology-to-Market Pilot Project

2015 Building Technologies Office Peer Review



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

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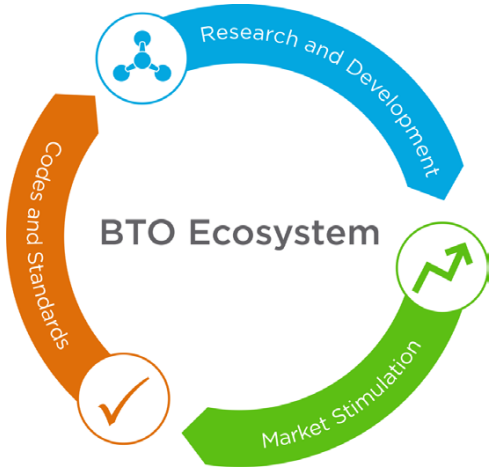
Technology-to-Market Program Year 1 Overview

- Lab/Industry Partnerships
- Budget: $2M DOE/BTO funding with industry cost share; jointly managed by Emerging Technology and Commercial Buildings Integration
- 11 proposals received, 4 accepted as part of merit review process. RCx Sensor Suitcase selected based on
  - Field test results
  - Strong market Interest
  - Compelling value proposition
  - Energy savings potential

- T2M Project Must-Haves
  - Strategic plan for addressing technical, commercialization and manufacturing barriers
  - Cost share and well-integrated feedback mechanism from industry partners
  - Commercialization pathway addressing full BTO ecosystem




Top 5 Reasons for BTO's Tech to Market (T2M) Projects
1. Support projects that bridge the gap between Research and Development and Market Stimulation. Even the most impactful technologies can end up in the valley of death without some support to bridge the gap between promising prototype and market ready.
2. Facilitate tech- transfer and commercialization activities and relationships.
3. Foster ongoing projects and partnerships between DOE, labs and manufacturers.
4. Cultivate the awareness of industry conditions to better bring technologies to market that address an unmet need.
5. Create a consistent process to help stakeholders better understand DOE and Laboratory roles and available opportunities for accelerating the voluntary adoption of high impact technologies .
At the end of T2M projects, the technology should be available to target markets for purchase through business-as-usual channels at market-acceptable payback rates.

Project Summary

Timeline:

Start date: Oct. 2013

Planned end date: Sept. 2017

Key Milestones

- Recruit manufacturing/vendor partner, 2015-01-30
- Recruit deployment partners, 2015-06-30
- Complete 3 real-building demos, 2015-08-30

Budget:

Total DOE $ to date: $1522K

Total future DOE $: $500K

Target Market/Audience:

- Overall: Commercial Buildings < 50,000 ft^2
- 1st Wave: Energy services & commissioning providers
- 2nd Wave: small building portfolio owners

Key Partners:

PNNL	Deployment Partner 1, TBD
LBNL	Deployment Partner 2, TBD
ORNL	Deployment Partner 3, TBD
Leviton	Deployment Partner 4, TBD

Project Goal:

Enable retro-commissioning in small buildings, realizing ~10% whole-building energy savings, by reducing implementation costs so that servicing this sector is cost effective with acceptable ROI. Work with both manufacturing/vendor and deployment partners to transform market.

Purpose and Objectives

Problem Statement

- Commercial buildings under 50,000 square feet, 95% of all buildings, do not typically have budgets or perceive the business case for retro-commissioning (RCx), thereby missing significant energy, cost and comfort improvements.
- They also do not have “in-house” staff with expertise in building systems, who can perform RCx or identify or implement improvements.
- Small commercial buildings have been notoriously difficult to reach for efficiency upgrades; therefore, tremendous savings opportunities exist. We estimate the national technical potential energy savings of this technology to be 0.8 quadrillion Btu of source energy.

Objectives

- Enable RCx in small buildings, and realize ~10% whole-building energy savings, by reducing implementation costs, including data collection and processing, so that servicing these buildings is cost effective with acceptable ROI.
- Transform the market at scale by working with supply (manufacturing/vendor) and demand (deployment) partners at every phase of the project.

Target Market and Impact of Project

Target Market and Audience:

- **Target Market**: Buildings without Building Automation Systems under 50,000 ft^2 - 44% of all commercial primary energy use
- **Audience**: Energy services and RCx providers expected to comprise the first wave of Suitcase technology adopters, followed by owners of large portfolios of small buildings, such as DoD, GSA and national accounts.

Impact of Project

- **Project Endpoint**: DOE involvement planned to conclude no later than 2017. manufacturing/vendor partner begins to mass produce and sell their version of the product. Deployers begin delivering RCx energy savings to small buildings.
- **Final Products**: Leviton developed/branded/supported product for sale in market. Catalyze provision of RCx service industry in small commercial sector.
- **Measuring impact** (or impact path)
  - Near-term (during or up to 1 yr. after project): Annual sales, # of RCx projects with Suitcase (+ energy savings), energy trade press coverage
  - Intermediate-term (1-3 yr. after project): new suppliers enter RCx market
  - Long-term (3 yr.+ after project): adoption of Suitcase in utility-scale programs

Energy Impact of Project

- In 2025, EIA projects commercial buildings will consume 18.8 quads primary energy (AEO 2014, Table 5)
- 44% of primary use is buildings under 50,000 ft^2 (CBECS 2003, latest available)
- Energy use in 2025 of small buildings: 8.2 quads.
- Sensor Suitcase target savings: 10% whole building, on average
- Technical potential savings, 2025: 0.8 quads/year
- Target date for mass production of technology: 2017
- In 2025, 5% market penetration of technology would yield savings of 40 Trillion Btu

Approach and Key Issues

Approach: Develop a "turn-key" hardware/software solution - the RCx Sensor Suitcase - that can be used by non-experts to automatically generate recommendations to improve building efficiency, operating costs, and comfort at low/no cost.

Key Issues

- Adequately validating technology performance.
- Engaging both manufacturing/vendor and deployment partners to successfully deliver the technology to market
- Working with manufacturing/vendor partner to define highest impact path to market and business models, given their specific supply, sales, and distribution channels.

Distinctive Characteristics

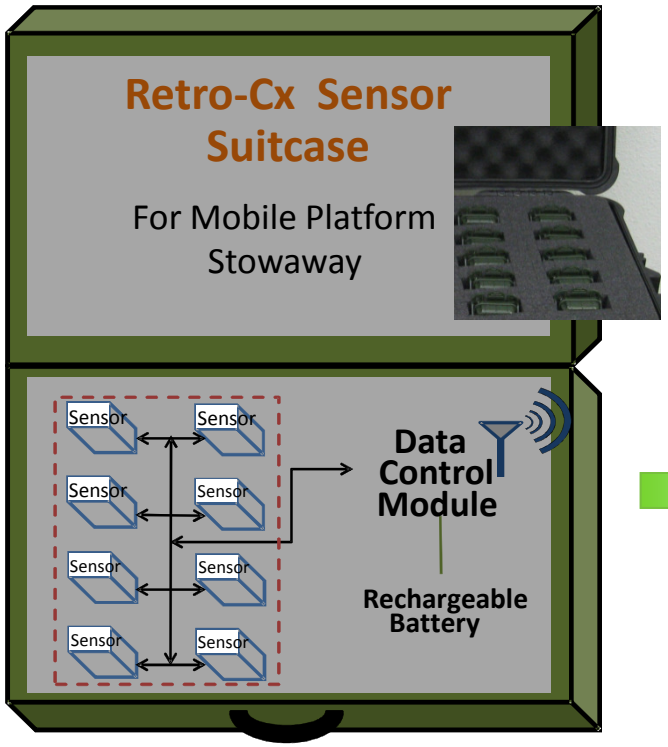
Distinctive Characteristics: The innovation offered lies in extensive streamlining of the RCx process for commercial buildings under 50,000 ft^2 thereby

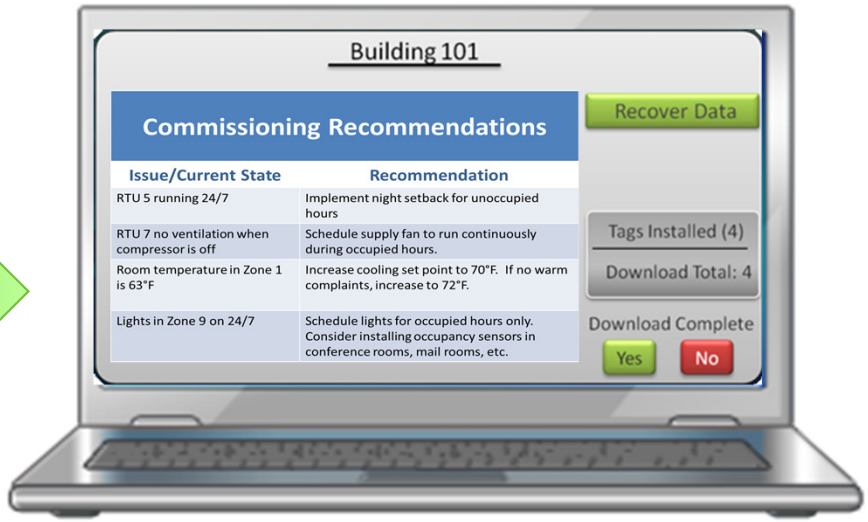
- Reducing labor costs through decreases in time and expertise required
- Enabling penetration of the small buildings sector, where low energy expenditures place tight constraints on payback and human capital investment
- Enabling nearly-fully automated identification of building performance improvement opportunities via innovations in sensor packaging and installation guidance

- **50% reduction in labor time/costs**
  - Guided, substantially automated sensor configuration and installation, in contrast to existing loggers, which require expertise to deploy properly
  - Software and sensors eliminate need for walk-through, spot measures, and engineering expertise to interpret data
- **Delivery of 10% average site whole-building energy savings**
  - Traditional labor-intensive RCx yields 16% median whole-building savings

RCx sensor suitcase system

1. Easy-install suitcase kit of sensors
2. Handheld device (e.g., Tablet)
3. Diagnostic algorithms
4. Software
5. Graphical user interfaces





Sensor Platform

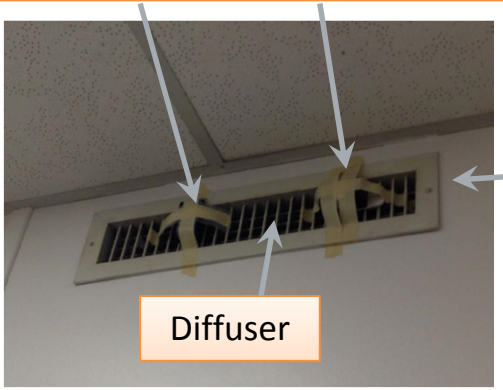
Sensor Battery

Handheld Device (e.g., tablet)

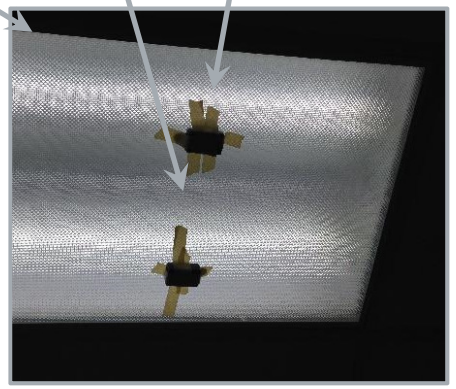
Tablet guides installation/retrieval of sensors

Conference room

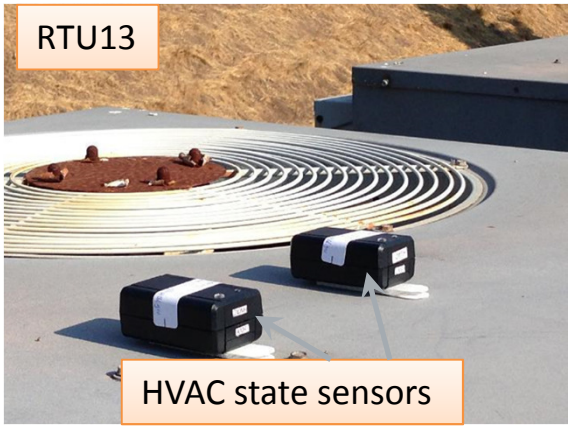
Diffuser air temperature sensors

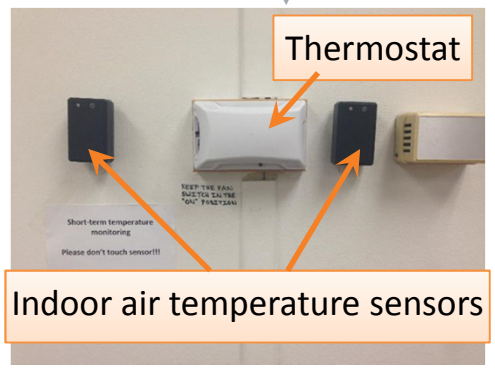


Lighting status sensors



Roof



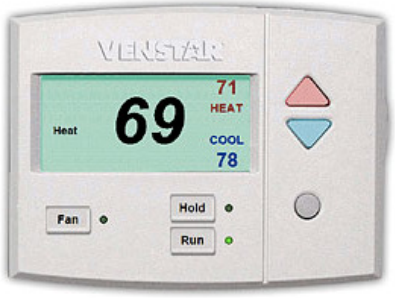


Roof

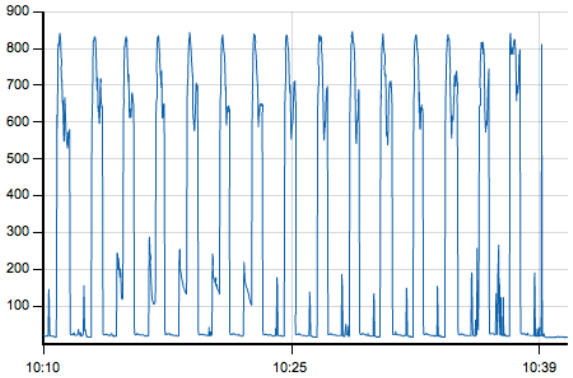
Diagnostic Algorithms

- 8 algorithms related to HVAC control, HVAC operation, lighting
- Most common, high-impact problems in small commercial buildings
- Rule-based algorithms, designed according to the available sensor types: Light, temperature, vibration for RTU status

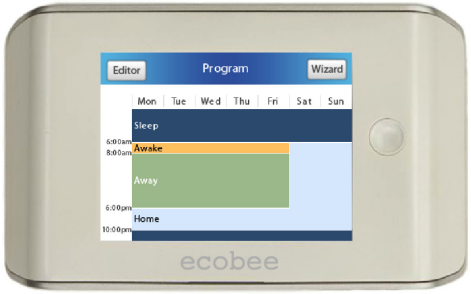
Set point dead bands,



RTU short cycling, not economizing

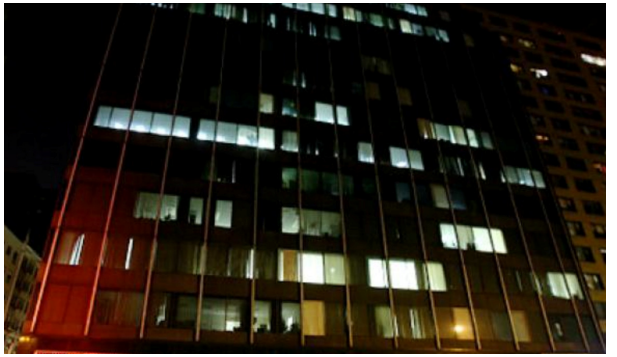


Scheduling, setbacks



Excessive daytime lighting

Excessive nighttime lighting



Software Output Report

User provides building details, occupancy schedule, utility expenses

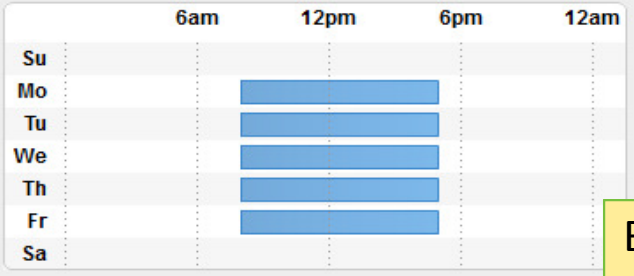
Start > Project > Building Recommendations

BLDG90

Utility Expenses

Gas:	3,230	$/year
Electricity:	4,042	$/year
Total:	7,272	$/year

Occupancy Schedule



Building Details

Owner:	Lawrence Berkeley Labs
Location:	East Campus
Address:	12 Main St.
Size:	10,000 sq.ft.
Timezone:	PST5PDT

Building details and occupancy also extracted from sensor data

Recommendations

Problem	Recommendation	Location	Savings ($/year)
Excessive lighting during occupied/daytime hours	Install occupancy sensors in locations with intermittent occupancy, or engage occupants to turn the lights off when they leave the area	151	70
Excessive lighting during unoccupied/nighttime hours	Install occupancy sensors in locations where it is not necessary or intended for the lights to be on all night, or encourage occupants to turn the lights off upon exit	151	50
RTU cycling on and off too frequently, potentially leading to equipment failure	Ask HVAC service providers to check refrigerant levels, thermostat location, and control sequences	151	70
Under use of free cooling, i.e., under-economizing	Ask an HVAC service contractor to check the economizer control sequence, unless the RTU does not have an economizer	151	330
Overly narrow separation between heating and cooling setpoints	Adjust the heating and cooling setpoints so that they differ by more than four degrees	151	40
Nighttime t enabled			420
Over-condi setpoint is			30
Over-condi setpoint is			3

Problems identified from the sensor data, **actionable recommendations**, and **estimated cost savings** from implementing recommendations

Total recommendations: 8

Total Annual Cost Savings **$ 1,013 / year**

Print to PDF | Close Building

Progress and Accomplishments - Overview

FY13-14

- Developed proof-of-concept prototype (FY13)
- Developed version 1.0 prototype (FY14)
- Successfully field tested prototype with independent 3rd parties (FY14)
- Confirmed significant market interest from user community

FY15

- Recruited major technology developer and manufacturer, Leviton, as manufacturing/vendor partner in January 2015.
- DOE, Leviton and labs held project kick-off meeting 17 March to align FY15 project plan with Leviton product development process and identify specific next steps.

Market Impact - Profile of Manufacturing/Vendor Partner

- Leviton
  - Portfolio of more than 25,000 products and 600 patents
  - Employs more than 6,500 people
  - Products include: connected home, electric vehicle charging, electrical wiring devices, lighting controls, network solutions, security & automation, submetering, temporary power
- Lighting and Energy Solutions, Tualatin, OR
  - 4 Vertical Markets: 1. Energy Controls, 2. M&V, 3. Architectural and Performance Control Systems, 4. Light Source Connectivity
  - New facility with labs for high power, electronics, field of view, validation testing, 3D printing, other
- Product Development Process
  - Typically fast concept-to-launch process, 9-12 months, given pace of technological change
  - Active use of Phase-Gate model, with go/no-go decision points
  - Management regularly evaluates product progress based on technical and market promise

Market Impact - Potential Users and Deployment Partners

Company	Business focus	Type of interest in suitcase
Abacus Property Solutions	Energy financing and services provider	Potential user
Arup Los Angeles	Architectural engineering	Potential user
Carbon Lighthouse	RCx for small to medium commercial and industrial	Potential user
Cygnus	Business media, market research, media platforms,	Promote RCx Suitcase in company conference, other media
Distributed Energy	Energy services provider	Potential user
EE Reports and greenec	Dynamic resource websites for energy efficiency contractors	Promote RCx Suitcase to their network of efficiency contractors
EnTouch Controls	Provider of small building energy management solution	Potential user
Facility Maintenance Decisions	An online magazine for facility manager and engineer	Promote RCx Suitcase to their network of facility mangers and engineers
GreenPath Energy Solutions	Energy Assessments, audits, and RCx provider	Potential user
Guam Power Authority	Utility	Potential user
H.L. Graves Air Conditioning	Mechanical contractor	Potential user
intellisenseio	Infrastructure monitoring and intelligence solutions	Potential user
McGeown Associates	Efficiency consultant	Potential user, utility program designer
McKinstry	Energy services provider	Potential user
Newman Consulting Group	Energy audits and RCx provider	Potential user
Preservation of Affordable Housing, Inc.	Owner of multifamily apartment buildings	Potential user
Puget Sound Energy	Utility	Potential user, utility RCx program manager
Wireless Glue Networks, Inc.	Software developer focused on DSM and device connectivity	Potential user
XCSpec	RCx provider, RTU monitoring and analytics	Potential user

Lessons Learned

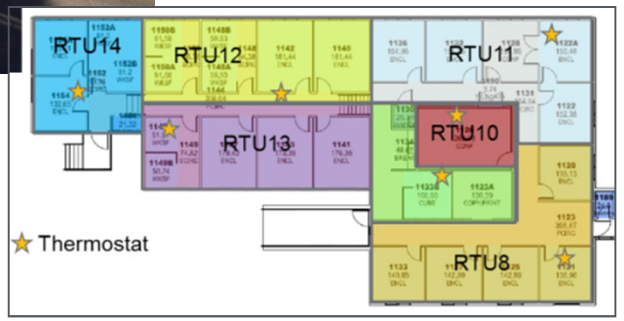
- In recent discussions with Leviton, we learned that
  - Case studies of performance in actual buildings are valuable to make the business case to invest
  - DOE/BTO connections to Federal sector (including via FEMP) and Better Buildings Alliance may provide relevant paths to market
  - Go/No-Go approach to innovation investments is actively employed

Awards/Recognition

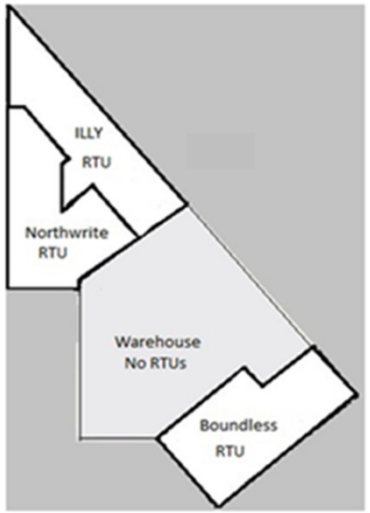
- RCx Sensor Suitcase included in ESource's "Top 22 Technologies and Trends of 2014," January 2015.
- RCx Sensor Suitcase selected as 1 of 8 projects in the UC Berkeley Haas School of Business Clean Tech 2 Market Program (C2M).
  - C2M is a partnership between students, scientists, engineers, and professionals at UC Berkeley to translate clean tech research into market opportunities.
  - C2M's selection committees include investors, tech transfer staff, and C2M faculty, alumni, sponsors and partners.
  - As one of the selected projects, RCx Sensor Suitcase is eligible for 1,000 hours of technology evaluation and market assessment from students and staff at Haas School of Business.

Accomplishments - Field test (FY14)

- Building size: 5,500 ft^2
- Location: Berkeley California
- Estimated annual utility expense: Electricity $5,985; Gas: $720



- Building size: 10,000 ft^2
- Location: Lake Oswego, OR
- Estimated annual utility expense: Electricity $5,320



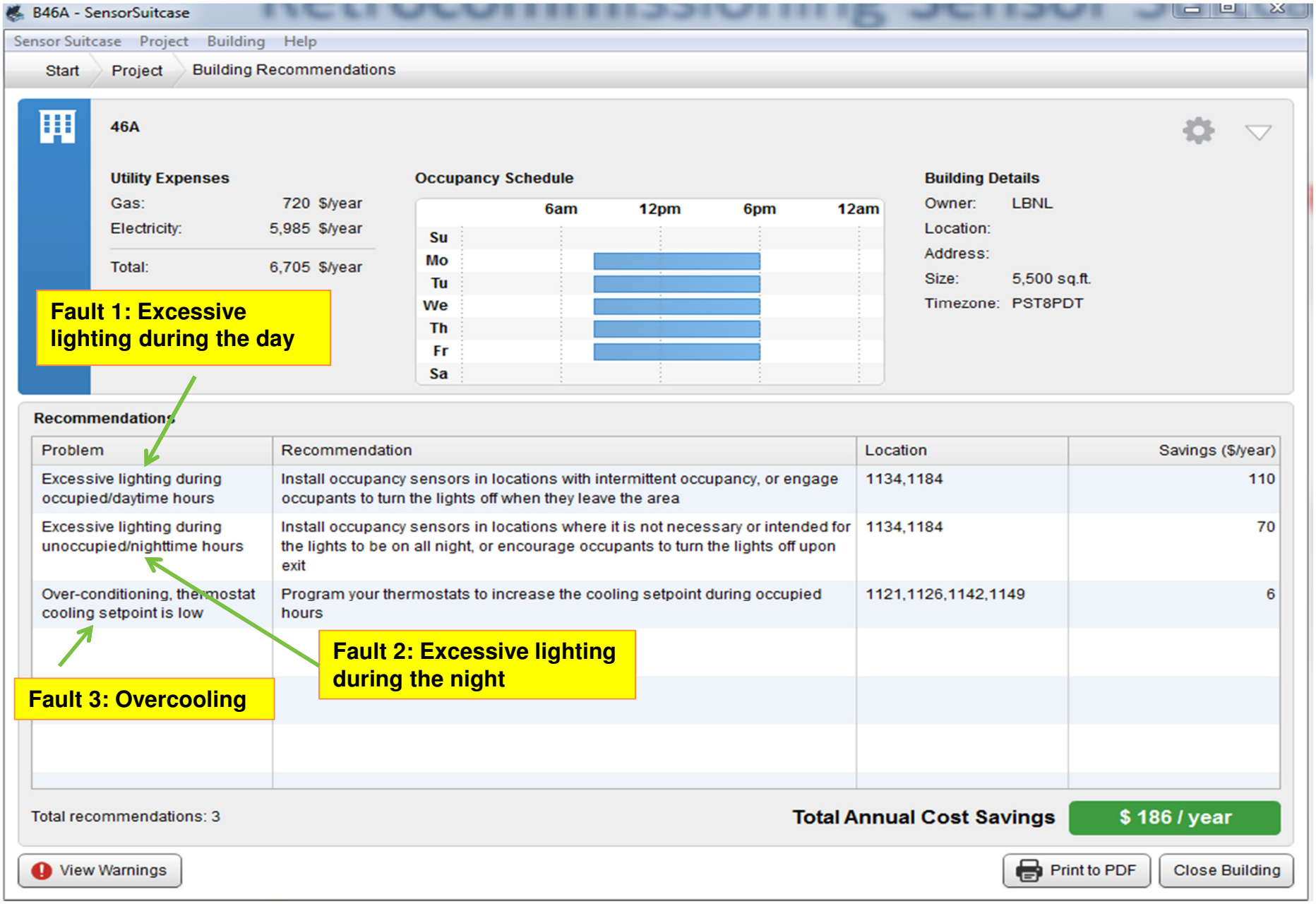
Accomplishments: Field Test Findings (FY14) - Hardware

- Users reported that hardware is well designed, and tablet to configure sensors is easy to use
- Most sensors were successfully field deployed
- Sensors collected data sufficient for analysis and problem identification
- Files successfully transferred to the analysis software.
- Valuable potential refinements identified for next phases of development
  - Minimizing impact of solar absorption on temperature sensors
  - Weatherproofing of outdoor sensors
  - Further validation of HVAC state sensing
  - Enhance or increase number of attachment mechanisms to accommodate a diversity of configurations
  - Lighter weight and compact suitcase
  - Additional signaling of status to user (e.g., with LED indicator lights)

Accomplishments: Field Test Findings (FY14) - Analysis Software

- Users reported that the software was easy to use, and the installation instructions were helpful
- Analysis outputs and recommendations "seemed reasonable" to users
- Analysis outputs and recommendations validated through separate analysis of sensor data by laboratory staff with building science expertise
- Refinement opportunities for next phase of development
  - Further vetting of diagnostic thresholds used in algorithms to identify problems
  - Further stakeholder feedback on necessity and value of utility cost information and associated savings estimates for each opportunity identified
  - Association of RTUs with zone ambient and diffuser air temperature sensors

Accomplishments: Example Analysis Software Field Test Output



Accomplishments – Positive Early Market feedback (FY14)

- Early market feedback* indicated strong interest from potential users
  - Guided sensor configuration and installation can significantly reduce labor time and required expertise
  - Technology is "*pretty versatile and could give you data where you wouldn't otherwise know what the actual operating conditions are*"
  - Price point of $1,000-$1,500 seems reasonable
  - Helps penetrate a market that's in "dire need"
  - Complements existing products and services
  - Direct-to-market is preferred delivery approach targeting clients of service providers and portfolio managers of small buildings

"We would use [the technology] as another tool of doing business. That fits well within our cost model."

* McKinstry, NorthWrite, KW Engineering, Exergetics, & Greenpath Energy Solutions.

Project Integration and Collaboration

Project Integration: By design, DOE Lab staff will work directly with Leviton and deployment partners on all phases of project – technical and market.

Partners, Subcontractors, and Collaborators:

- Leviton – manufacturing/vendor partner
- TBD – industry deployment partners (via RFI and Leviton input)
- PNNL – original hardware developer and electronic/firmware enhancements for second prototype
- LBNL – original analysis software developer
- ORNL – second prototype hardware fabricator and developer of mechanical enhancements for second prototype

Communications - Presentations

- BTO Sensors and Controls Program Overviews 2013, 2014
- California Cx Collaborative, Fall 2014 Meeting
- Keiretsu Forum (investors/entrepreneurs, part of LLNL speaker series)
- ASHRAE 2015 Annual Conference

Next Steps and Future Plans

Leviton, DOE, DOE Labs held project kick-off meeting 17 March to align FY15 project plan with Leviton product development process. Team identified specific near-term actions:

- Rapidly develop first order analysis of market potential
- Share detailed technical documentation on software/hardware with Leviton to provide greater understanding of current prototype system
- Identify highest priority enhancements of suitcase prototype
- Proceed with plan to complete 3 additional building demonstrations of lab-developed prototype.
- Proceed with plan to recruit deployment partners.
- Review intellectual property aspects of technology.

Next Steps and Future Plans (2)

2016

- Leviton will design a next-generation/full prototype product, tailored to their existing designs and preferred hardware architectures.
- Labs to provide technical assistance; business plan updated.

2017

- Leviton will commence mass production and final testing of the commercial product, finalization of business and marketing plans, and product launch.

NOTE: The timeline is drawn from the FY15 AOP, and not confirmed with Leviton, which typically works on much faster product development timelines.

REFERENCE SLIDES

Project Budget

Project Budget: $1522K FY13-FY15, covering design, development, fabrication, testing, documentation

Variances: None

Cost to Date: Spending is on track relative to tasks and schedule – $127K of $602 FY15 funding allocation has been spent through 3/20/2015.

Additional Funding: TBD by DOE

Budget History					
FY2013– FY2014 (past)		FY2015 (current)		FY2016 – 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$920K		$602K	TBD	500	TBD

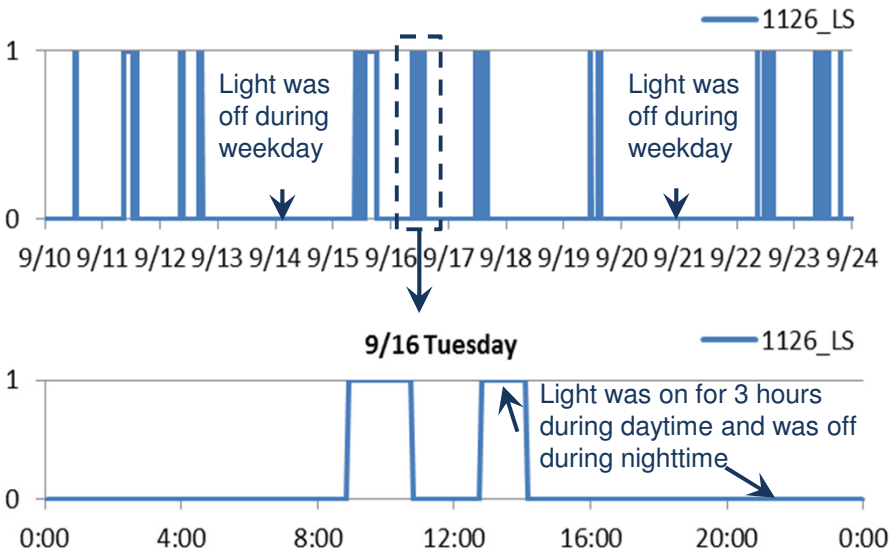
Project Plan and Schedule

Project Schedule												
Project Start: 10/1/2012		Completed Work										
Projected End: TBD		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned) use for missed milestones										
		Milestone/Deliverable (Actual) use when met on time										
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Four Retro-Cx suitcases fabricated								◆				
Field demonstrations started				◆								
Field demonstrations completed								◆				
Current/Future Work												
Recruit a manufacturing partner										◆		
Letter of commitment from one or more deployment partners											◆	
Acceptable range of labor cost savings, RCx measure identification, and associated energy savings that will define a successful field test of the equipment is agreed upon by partners, lab team, and DOE.											◆	
Completion of at least 3 successful real-building demonstrations that incorporates initial feedback from partners.												◆
Preliminary Market Assessment Report and Initial Commercialization Path to Market Plan												◆

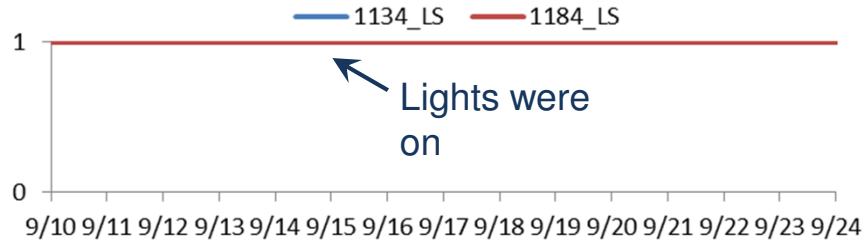
Accomplishments: Diagnostic Algorithm Validation, Lighting

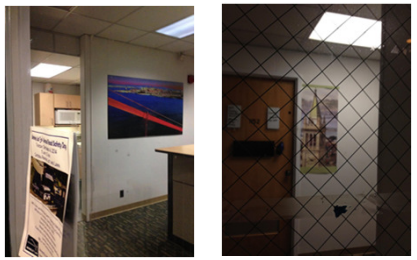
Software results agree with trend data inspection

- **Conference room** 1126
- Software did not identify the presence of lighting faults
  - **Lights only on in limited time periods during daytime**
  - **Lights off during nighttime and weekends**
  - **No excessive lighting**



- **Hallway** 1134 and 1184
- Software identify the presence of lighting faults
  - **Lights always on, day and night**
  - **Excessive lighting is flagged for both daytime and nighttime**



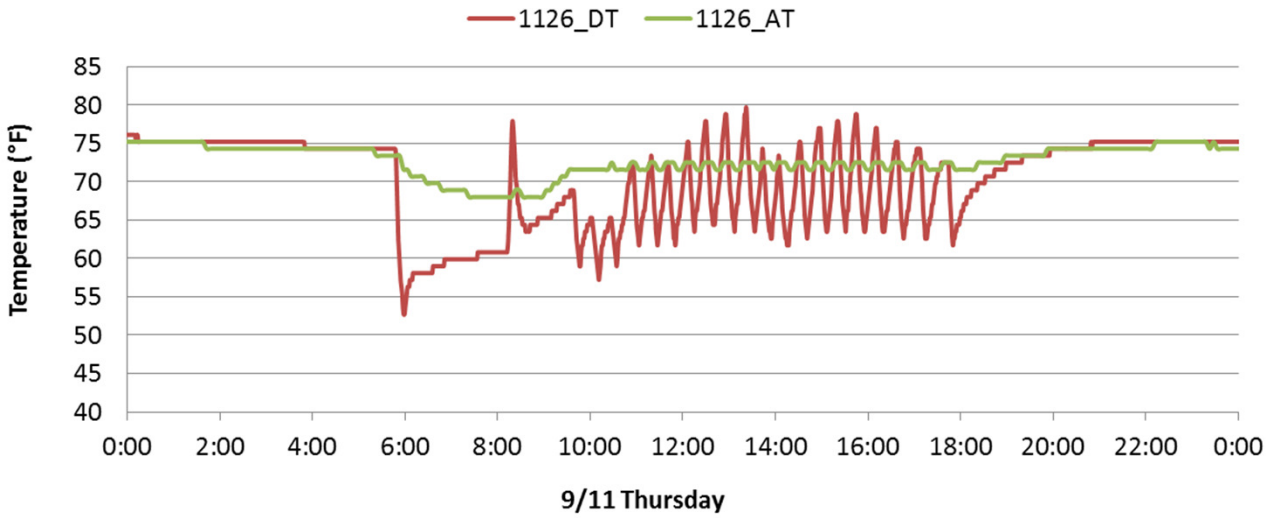


Hallway 1134 and 1184 at night

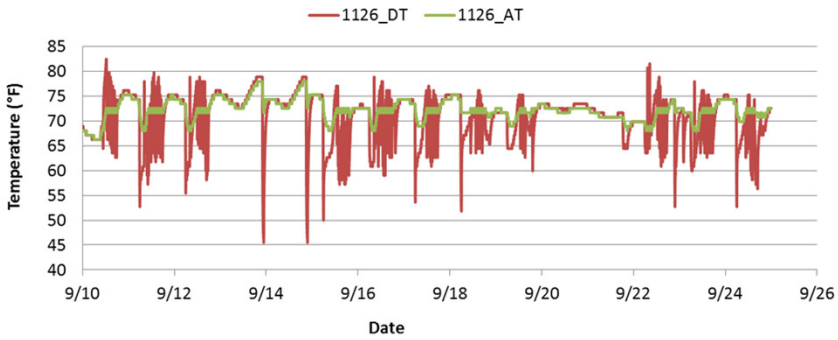
31

Accomplishments: Diagnostic Algorithm Validation, HVAC Operations

- Software results agree with trend data observation
  - **Cooling setpoint too low** during occupied hours (**green** line at ~73°F during daytime hours)
  - Algorithm provides **reasonable output when only indoor ambient (AT) and diffuser air (DT) temperature sensors were available**, due to damaged HVAC state sensor



*Room 1121, 1142 and 1149 have similar data trends



AT: Indoor ambient temp; DT: Diffuser air temp;

32