Getting Beyond Widgets: Developing Utility Programs for Building Systems

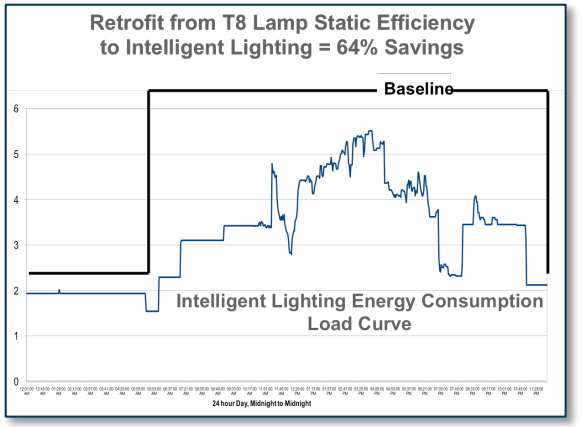
ACEEE Summer Study on Energy Efficiency in Buildings

Lawrence Berkeley National Laboratory
Energy Technologies Area

Utility DSM Challenges

- DSM Portfolios currently set up for widgets
  - Technical Reference Manual doesn't cover systems
  - Deemed savings approaches are suited towards 'widget' technologies
- Custom DSM programs require higher levels of technical assistance and incur higher delivery costs – not viable for small commercial
- Subset of cost-effective energy-saving component technologies are becoming smaller with increasingly more stringent code
- ET feeds the DSM program pipeline, but ET assessments and white papers are currently not sufficient to translate integrated system opportunities into action

Photo Courtesy of: Shenzhen HSG LED Lighting Co., Ltd.



However – Set of cost-effective energy-saving component technologies are becoming smaller with increasingly more stringent code. Systems provide:

- Access to a wider set of deep, energy saving technologies
- Greater energy savings yields

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Integrated Systems – Realizing Deep Energy Savings

Numerous case studies show that integrated systems can result in deep energy savings…

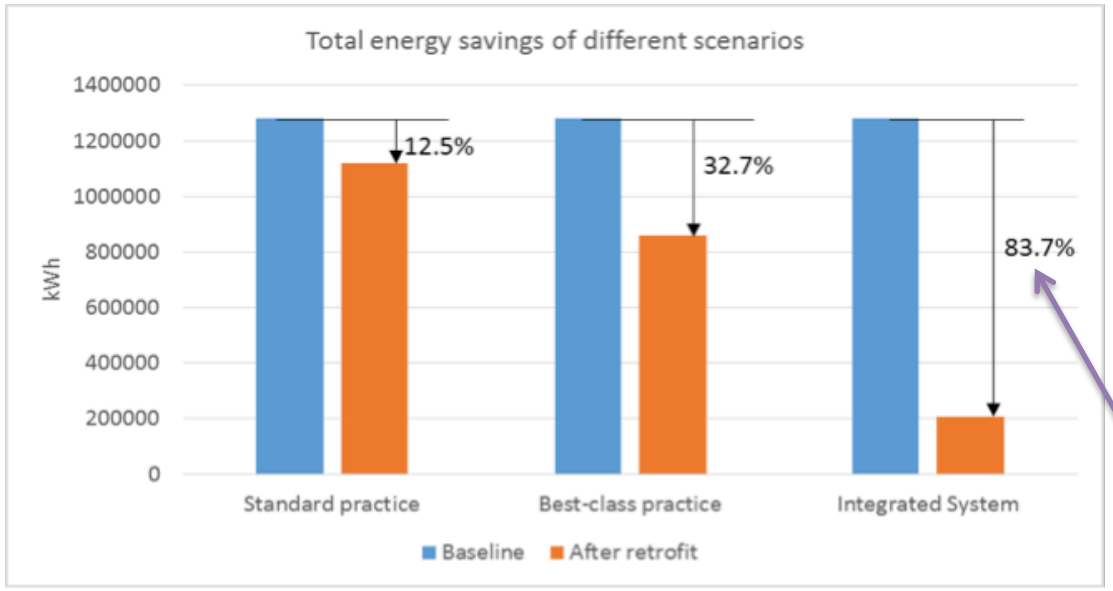

Figure: Comparing Two Approaches of Component Level Equipment Replacement in a Whole Building Retrofit to a Whole Building Integrated System Approach [DRAFT - Regnier et al, 2016]

Component equipment replacements alone will not meet state and federal energy savings goals (e.g. CA 2030 net zero, 50% energy savings)

An integrated systems approach is needed

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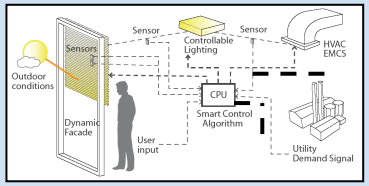
DOE-LBNL Project – Beyond Widgets, Systems Programs for Utilities

Goal: Develop validated Building Systems Packages for utility energy efficiency incentive programs

- Working with at least 3 utilities, develop packages for at least 3 systems

Building Systems Program Package



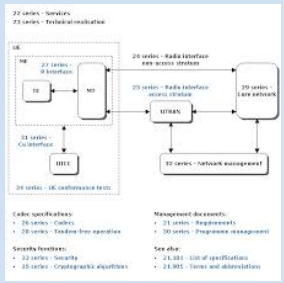
System specifications

Savings & performance metrics

M&V specifications

FLEXLAB-validated Savings

Controlled testing and validation of systems



Savings persistence guidance

Assessment method and system implementation guidelines

Systems and Partner Utilities

	System	Market	Whole Building Potential Savings
ComEd An Exelon Company	Automated shading integrated with daylighting controls	Med-large office K-12 Educational	9-23%[1]
Xcel Energy℠	Daylight redirecting window film integrated with daylight dimming	Med-large office	17-33%[2]
A PUBLIC AGENCY NCPA NORTHERN CALIFORNIA POWER AGENCY; SCPPA	Integrated task/ ambient lighting with plug load occupancy-based controls	Small-large office	17-27%[3]

Notes:

1. Compared to DOE benchmark 1980s era building, with range of glazing VT and LPDs.
2. Compared to ASHRAE 90.1-2010 (CO) and ASHRAE 90.1-2013 (MN).
3. Compared to CEUS average small (17% result) and large (27%) commercial office baseline.

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FLEXLAB – Facility for Low Energy eXperiments in Buildings

- LBNL developed FLEXLAB, DOE's unique facility dedicated to:
  - Developing & validating solutions for highly-efficient, **integrated building systems under realistic operating conditions**
  - Research focus includes:
    - Systems integration at end use, whole building & grid interaction levels
    - End use integration & component interactions (e.g., HVAC, lighting, windows, envelope, plug loads control systems)
    - Controls hardware & sensors
    - Simulation & tools for design through operations
- Commercial buildings focus, with applications relevant to office, retail, educational, multi-family
  - New construction & retrofit
- Energy efficiency studies, including thermal & visual comfort & occupant engagement

ComEd Automated Shading/Dimmable Lighting FLEXLAB Test

ComEd FLEXLAB Test Parameters

Test Objectives

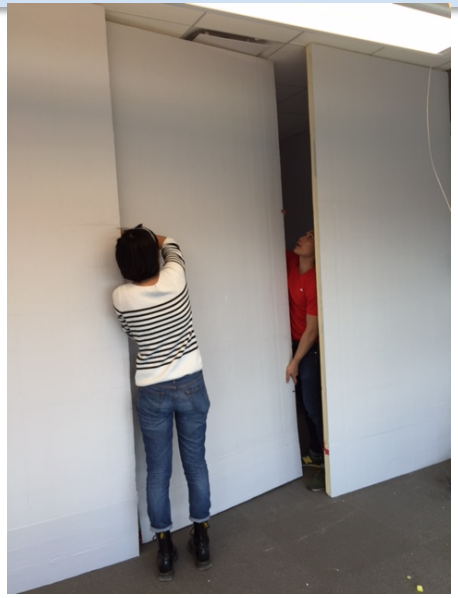
- Analyze lighting & HVAC energy savings attributable to just shading and controls, for Chicago weather. Include basic evaluation illuminance and glare.
- Evaluate level of effort and uncertainty associated with different levels of M&V.

Test Parameters

- Orientation: South, West
- Window-to-Wall Ratio: 0.40, 0.30
- Depth of daylit zone: 15ft (closed office), 25ft (open office)
- Lighting type: T-8 Pendant, LED Pendant

ComEd FLEXLAB Test Setup

Licor sensor grid and HDR cameras



Partitioning for 15' zone

Paneling for lower window-to-wall ratio

Occupant heat generators

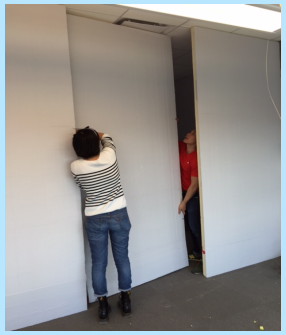
ComEd FLEXLAB Test Setup

Multiple test configurations

Orientation
South, West

Window size
0.3, 0.4 window-wall ratio

Daylight zone
10', 15', 25' depth



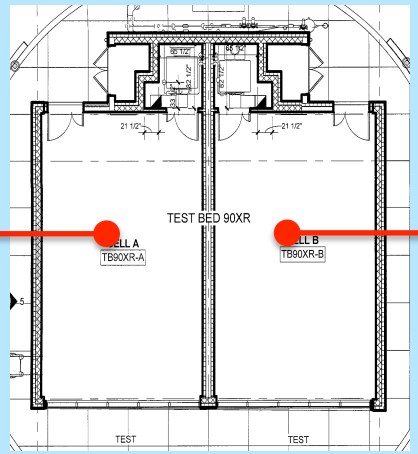
movable walls to change zone depth

Lighting type
T-8, LED

Baseline Comparison

Cell A represents a baseline with venetian blinds and no dimming. All other system features and operations are identical, allowing for a true 'controlled' experiment.

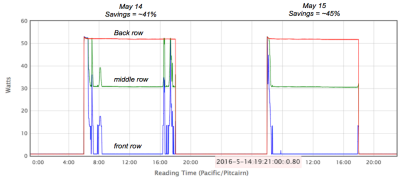
Cell A
Baseline



Cell B
Test Case

Extensive Metering

allows for detailed analysis of each component and end use



Adjusting for Climate

Internal temperature setpoints are adjusted in real time to match the indoor-outdoor temperature difference in Chicago. This provides realistic estimates of HVAC loads for Chicago climate.

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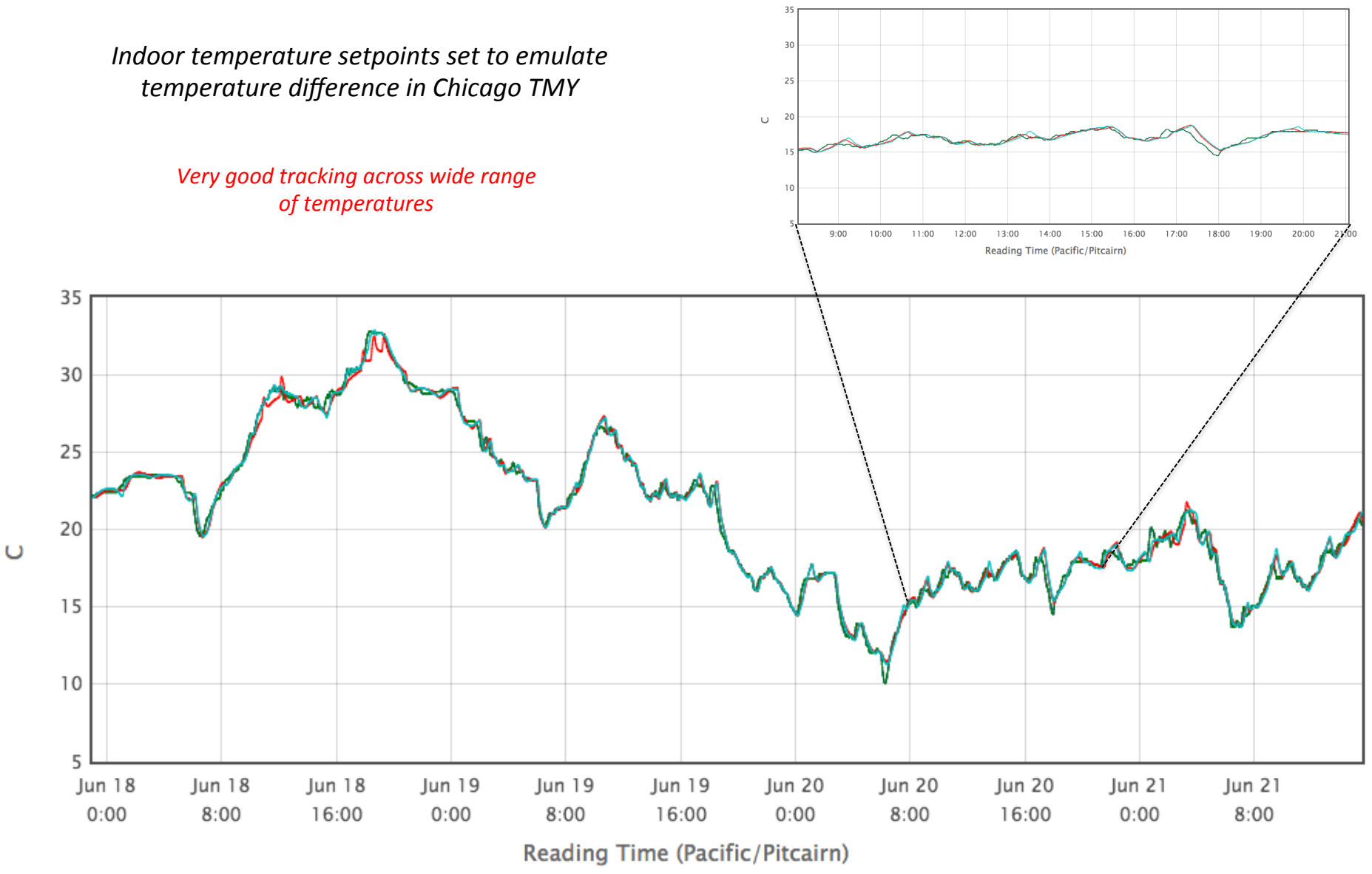
Automated Shading & Daylight Dimming Preliminary Test Results – Climate Tracking

Indoor temperature setpoints set to emulate temperature difference in Chicago TMY

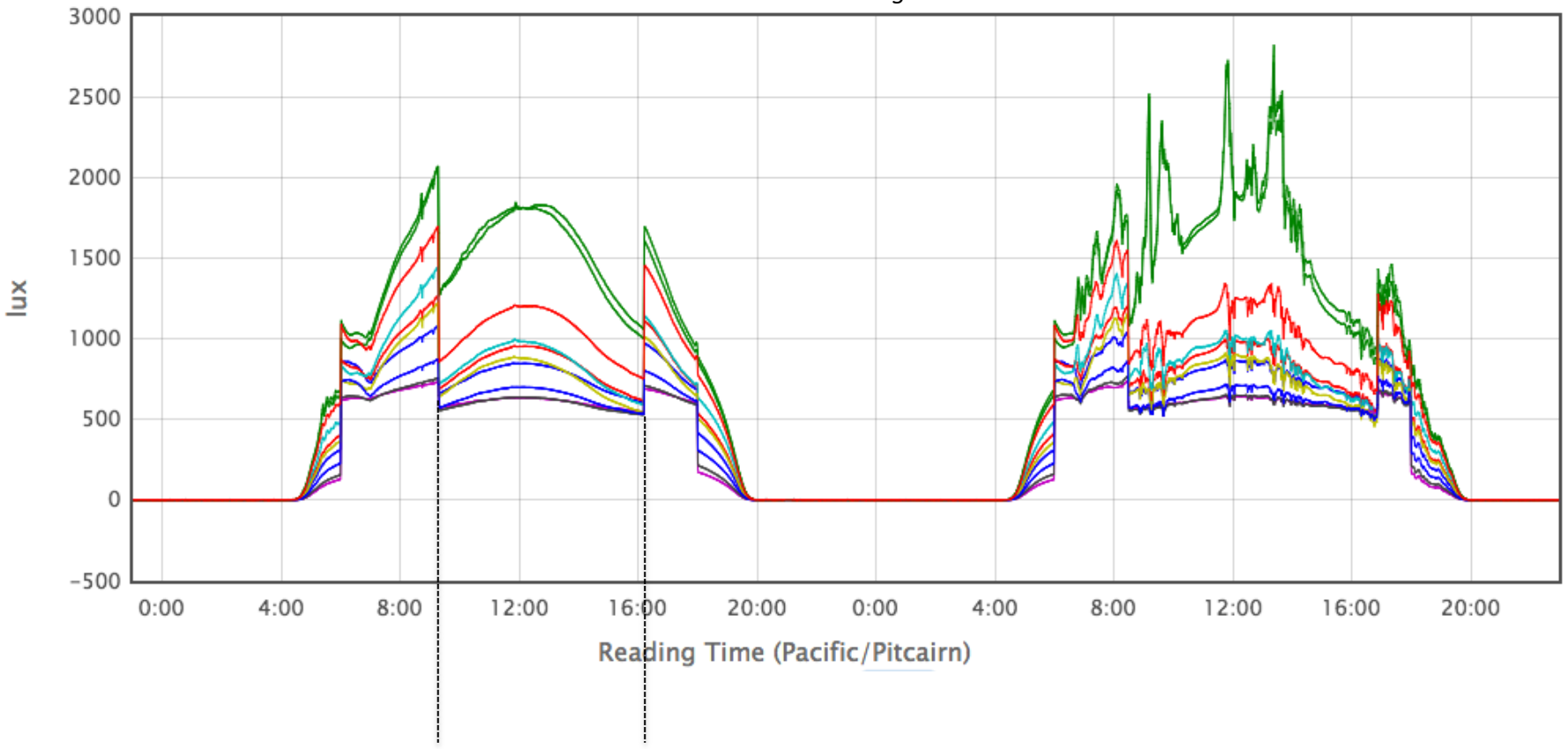
Very good tracking across wide range of temperatures



Automated Shading & Daylight Dimming Preliminary Results – Light Levels

Workplane Illuminance at 3' intervals from window

South Facing



Shades deployed *Shades retracted*

Automated Shading & Daylight Dimming Preliminary Results – Visual Comfort

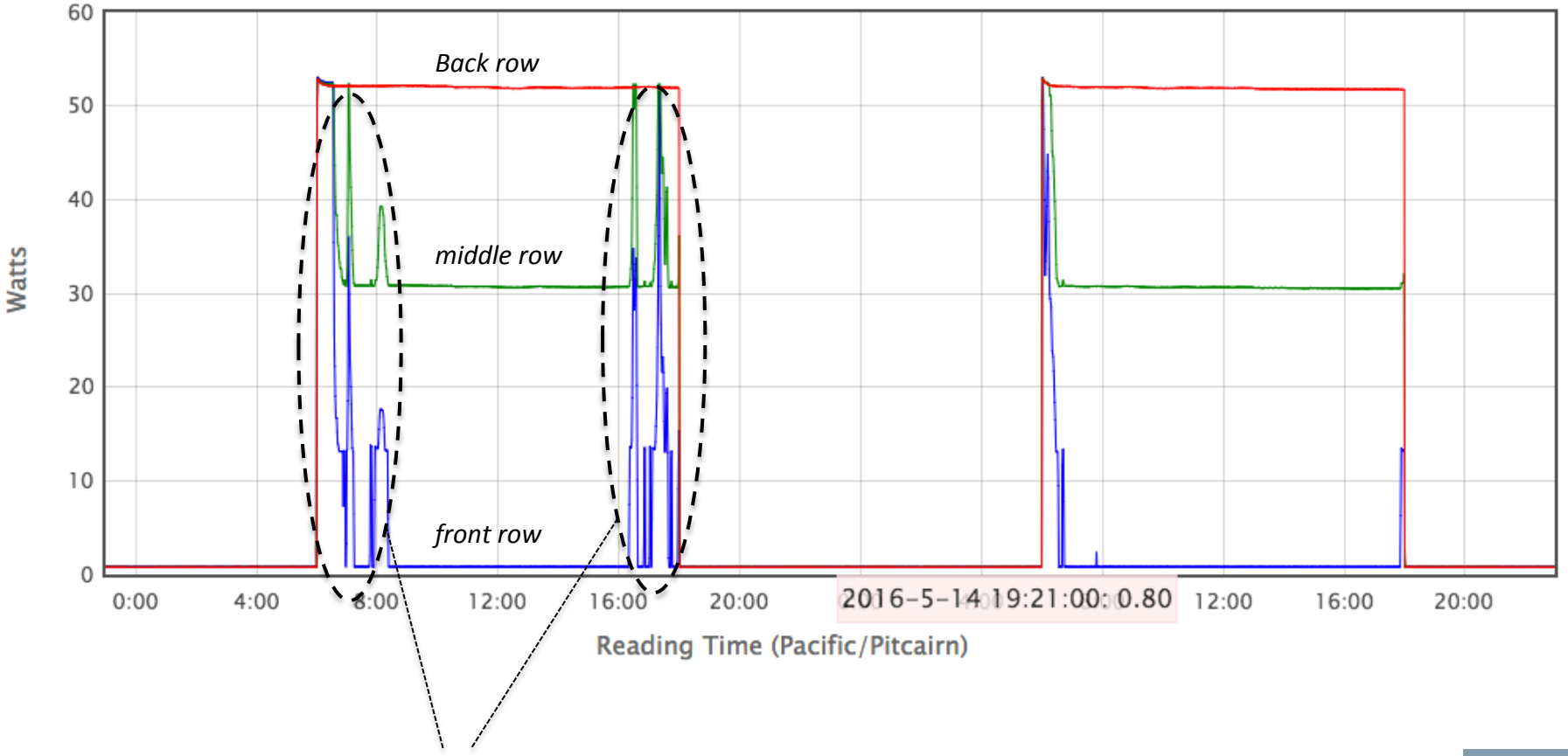
HDR camera images

Automated Shading & Daylight Dimming Preliminary Results – Lighting Energy

Normal South Facing

May 14
Savings = ~41%

May 15
Savings = ~45%



Less dimming ~7-9 am and ~5-7pm on May 14 vs. May 15

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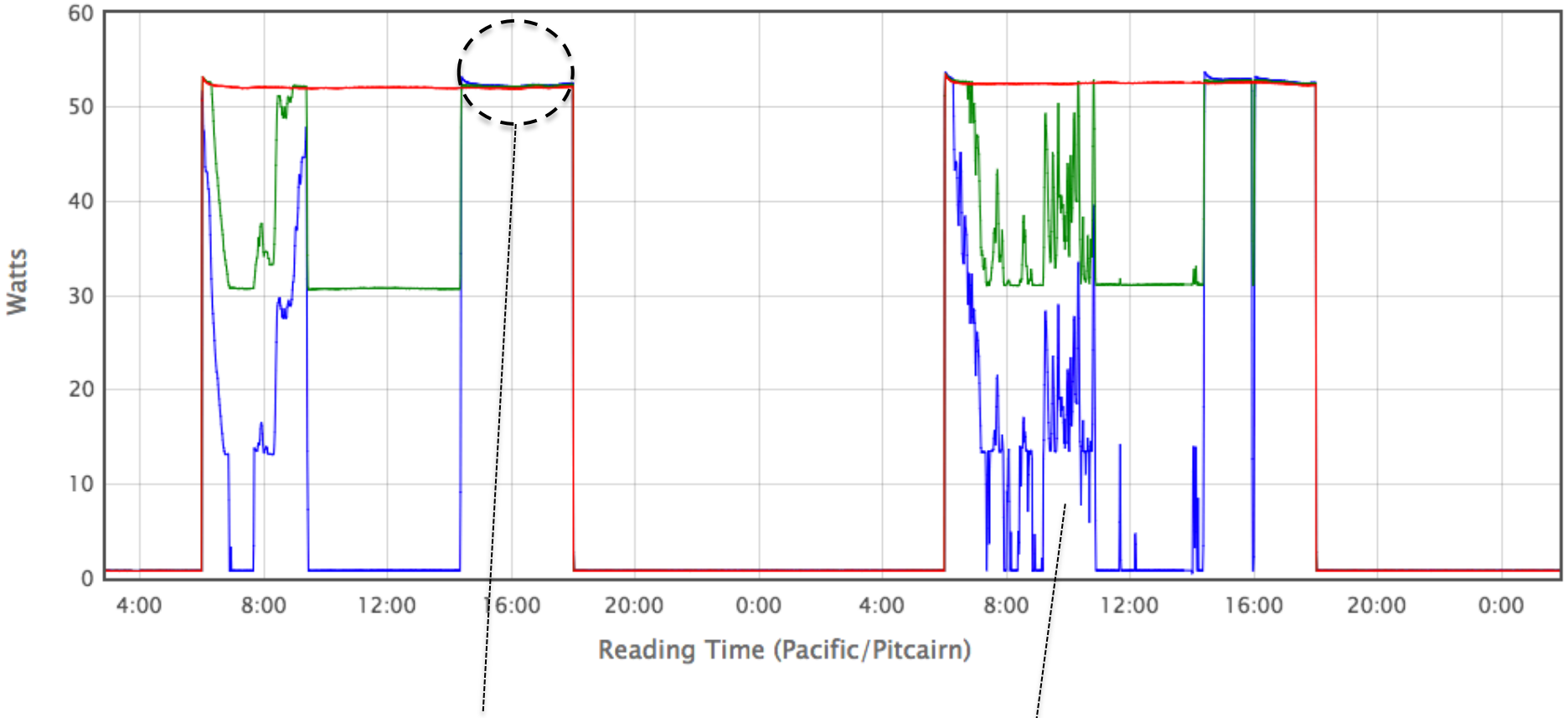
Automated Shading & Daylight Dimming Preliminary Results – Lighting Energy

Normal West Facing



Shades fully deployed, no dimming after ~3pm

Less dimming in morning compared to south facing

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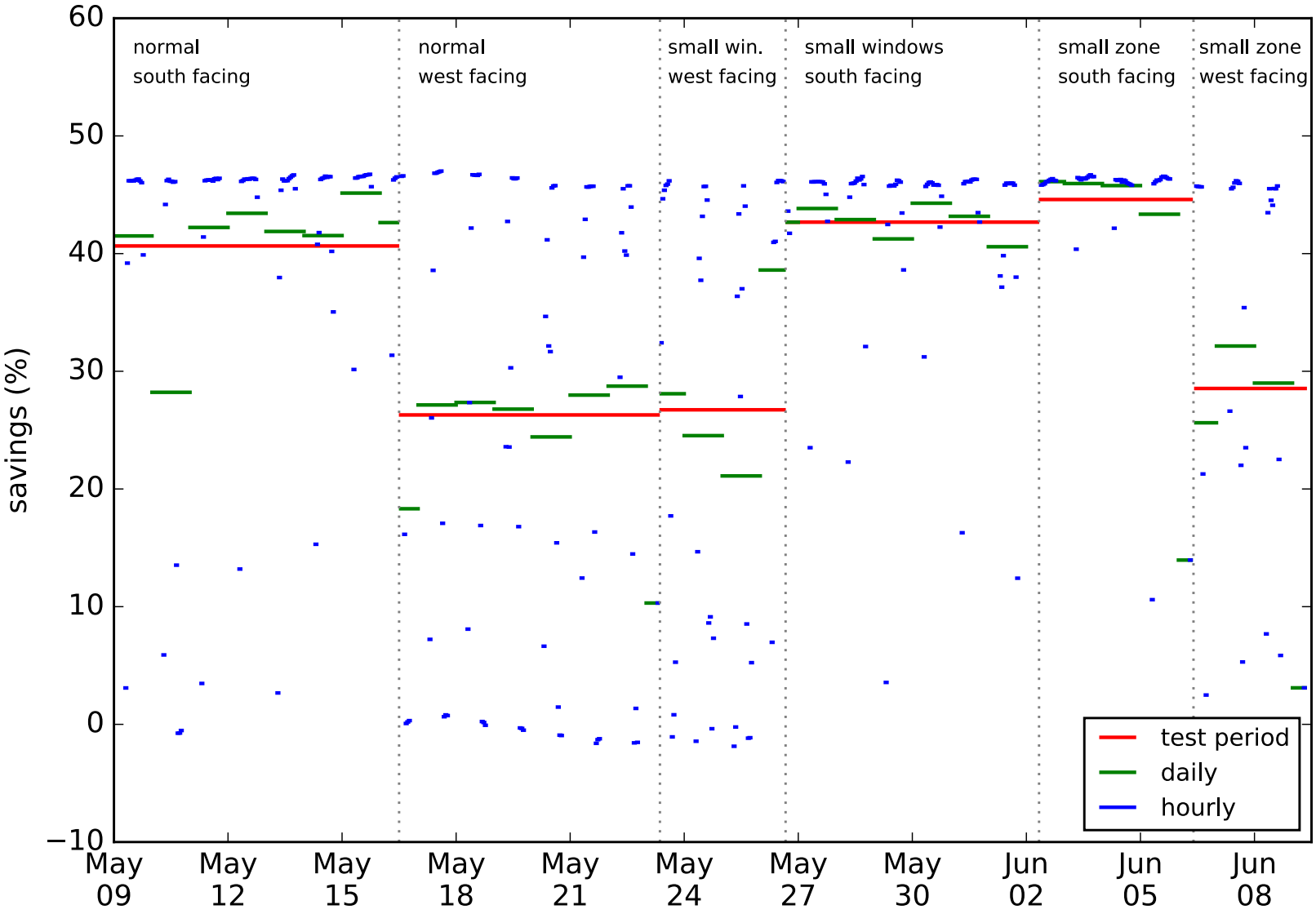
Automated Shading & Daylight Dimming Preliminary Results – First Rounds of Tests

6 configurations tested to date

Lighting energy savings: 40-45% south; 25-30% west



CA POU: Task-Ambient Lighting and Plug Load Controls

2 Technology Package approaches:

Package 1 - The plug-and-play nature of the overhead lighting retrofit does not trigger Title 24 Energy Code.

- Existing building energy use is used as the baseline
- Troffers or pendants, T12 or T8 to linear LED replacement lamp (tuned or static output depending on existing case) for overhead; LED task lights
- Overhead lighting evaluated with and without existing scheduling and occupancy controls as well
- Occupancy-based plug load control

Package 2 - Modifications-in-place or alterations trigger Title 24 Energy Code.

- Both existing condition and Title 24 baselines will be used
- Troffer or pendant replacement, T8 or T5 to LED with manual on/off, scheduling, occupancy controls, tuning; LED task lights
- Occupancy-based control of overhead lighting and plug loads

Plug load and task light operations are based on occupancy sensor and schedule controls in both TP1 and TP2

Task/Ambient Lighting and Plug Load Occ Controls: Market Analysis Results

Input estimates to market analysis for system performance based on published field test results and current product costs.

- Package 1 costs: $2.74 - $4.67 / sqft
- Package 2 costs: $4.54 - $7.74 / sqft

- Package 1 energy savings: ~2.8 kWh / sqft / yr (16% whole building)
- Package 2 energy savings: ~4.4 kWh / sqft / yr (21% whole building)

Utilities typically use Total Resource Cost as a critical pass / fail for individual programs, with values =>1 indicating a pass.

- Package 1 TRC values (RET): 1.04 → 1.23
- Package 2 TRC values (RET): 1.19 → 2.17

Variations in TRC due to local utility rates / avoided costs (analysis split into northern and southern California geographies) and also reflects a range in market adoption (industry expert inputs)

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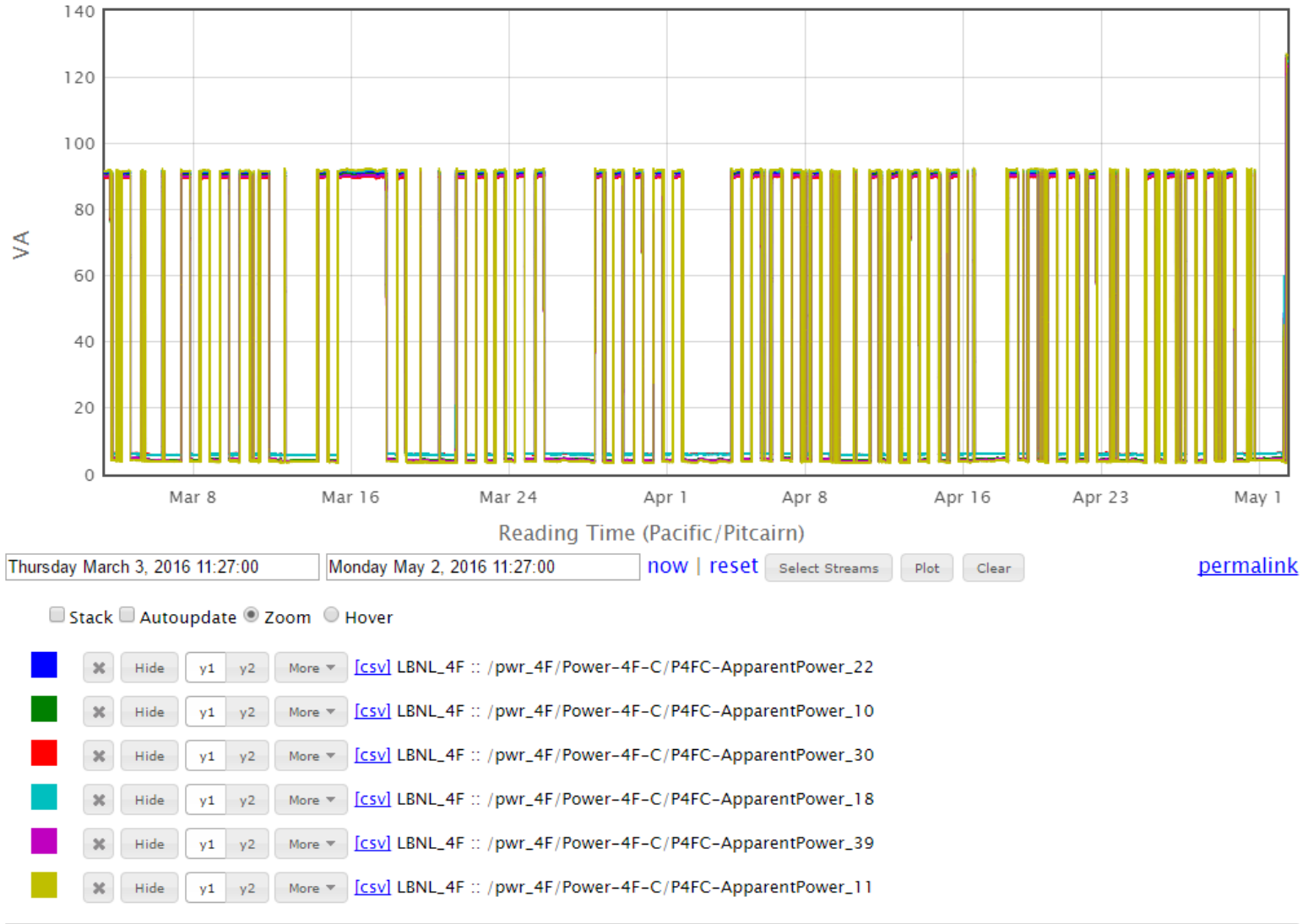
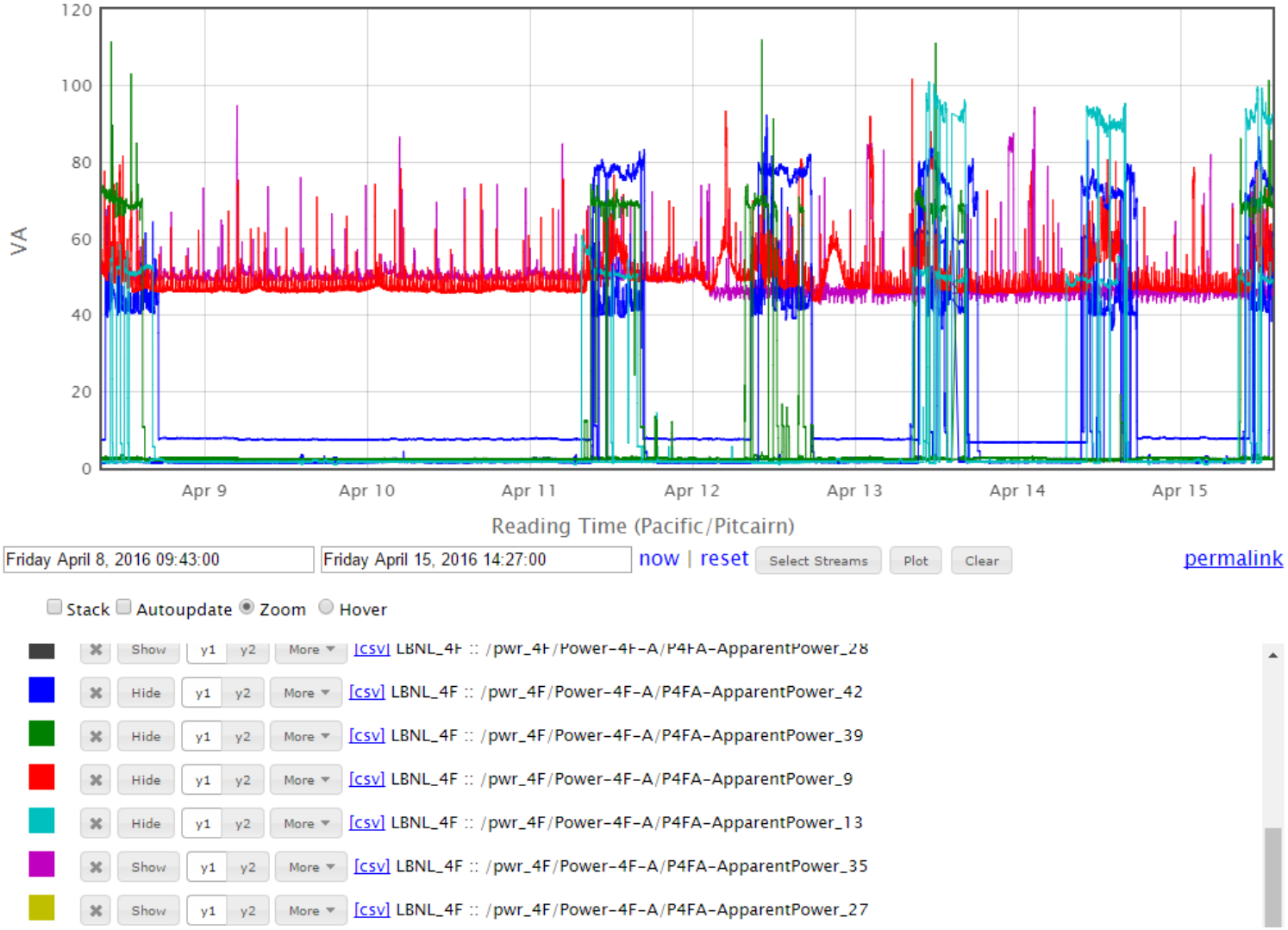
Preliminary Test Results - Overhead Lighting Energy

Overhead Lighting Circuit Energy – Zonal Level Occupancy Control



Preliminary Test Results – Plug Load Energy

Controlled Plug Load Circuit Energy – Workstation-level occupancy control



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Test 1 – Preliminary Results

Systems Performance – Test 1

Overhead Lighting Energy Savings

Large Office	Baseline (kWh/sqft/yr)	Test EUI (kWh/sqft/yr)	First Cut Lighting Savings (kWh/sqft/yr)	% Savings	Anticipated Test EUI (kWh/sqft/yr)	Revised Lighting Savings (kWh/sqft/yr)	% Savings
Measured Baselir	7.21	1.96	5.25	73%	1.53	5.67	79%
SMUD	4.73	1.96	2.77	59%	1.53	3.20	68%
SCE	4.7	1.96	2.74	58%	1.53	3.17	67%
SDGE	4.45	1.96	2.49	56%	1.53	2.92	66%
PGE	4.24	1.96	2.28	54%	1.53	2.71	64%

Plug Load Energy Savings

Large Office	Baseline (kWh/sqft/yr)	Plug Load Savings (kWh/sqft/yr)	% Savings	Anticipated Test EUI (kWh/sqft/yr)	Revised % Energy Savings	Plug Load Savings (kWh/sqft/yr)	Anticipated Test EUI (kWh/sqft/yr)
Baseline	4.91	0.40	8%	4.50	10%	0.48	4.43
SMUD	5.04	0.42	8%	4.62	10%	0.49	4.55
SCE	3.37	0.28	8%	3.09	10%	0.33	3.04
SDGE	2.96	0.24	8%	2.72	10%	0.29	2.67
PGE	3.72	0.31	8%	3.41	10%	0.36	3.36

Total Savings and Economic Performance

Large Office	Capital Cost ($/sqft)	Energy Savings (kWh/sqft/yr)	Energy Cost Savings	Payback (yrs)	System Energy Savings	WB Energy Savings - Low	WB Energy Savings - Low
Measured Baselir	5.61	6.15	0.99	5.67	48%	35%	47%
SMUD	5.61	3.69	0.59	9.45	36%	18%	28%
SCE	5.61	3.49	0.56	9.98	34%	19%	27%
SDGE	5.61	3.20	0.52	10.88	32%	15%	24%
PGE	5.61	3.07	0.49	11.36	31%	17%	23%

Test 2 – Preliminary Results

Technology package 1 (basic)

Overhead lighting –

- Replacement of T5 HO tubes with T5 LED replacement tubes with integrated driver. Baseline had T5 HO-based lighting running 24/7 as occupants do not tend to use manual switches to turn off lighting. Similar observations were present for the test case, where 24/7 operations prevailed. The results in table below assume a 60 hour working week (14 hour weekdays) and a sweep of lighting operations for the test case.
- Significant savings arise from this sweep against the baseline, but it seems perfectly reasonable to assume similar sweeps will be present in the 'average' office buildings for the respective IOU territories presented in the table.

Plug load –

- Occupancy based control of all non-critical desktop equipment (i.e. everything except computers and laptops). No printers/copiers are controlled by occ sensors – control of network printers and copiers may yield additional significant savings.

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Test 2 – Preliminary Results

System Performance: Test 2

Measured Overhead Lighting Energy Savings

Large Office	Baseline (kWh/sqft/yr)	Test EUI (kWh/sqft/yr)	Lighting Energy Savings (kWh/sqft/yr)	% Savings	Test EUI + Sweep (kWh/sqft/yr)	Lighting Energy Savings (kWh/sqft/yr)	% Savings
Measured Baseline	6.57	3.39	3.18	48%	1.41	5.16	79%
Indicative T24 Baseline	2.55	3.39	(0.84)	-33%	1.41	1.14	45%
SMUD	4.73	3.39	1.34	28%	1.41	3.32	70%
SCE	4.7	3.39	1.31	28%	1.41	3.29	70%
SDGE	4.45	3.39	1.06	24%	1.41	3.04	68%
PGE	4.24	3.39	0.85	20%	1.41	2.83	67%

Plug Load Energy Savings

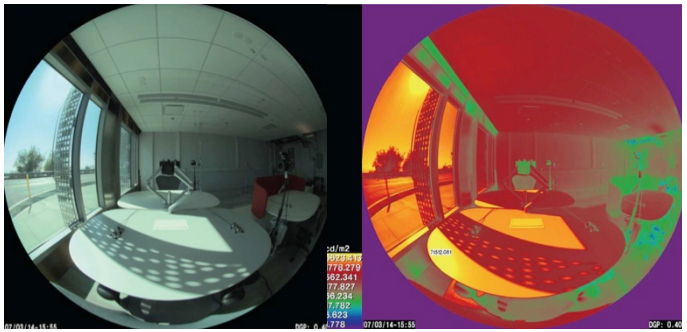
Large Office	Total Baseline EUI (kWh/sqft/yr)	Plug Load Savings (kWh/sqft/yr)	% Savings	Anticipated Test EUI (kWh/sqft/yr)
Measured Baseline	5.28	0.54	10%	4.74
Indicative T24 Baseline	2.96	0.31	10%	2.65
SMUD	5.04	0.52	10%	4.52
SCE	3.37	0.35	10%	3.02
SDGE	2.96	0.31	10%	2.65
PGE	3.72	0.38	10%	3.34

Lighting and Plug Loads Energy Savings

Large Office	Energy Savings (kWh/sqft/yr)	Energy Cost Savings ($/sqft/yr)	System Energy Savings	WB Energy Savings - Low	WB Energy Savings - Hi
Measured Baseline	5.71	0.92	48%	N/A	N/A
Indicative T24 Baseline	1.45	0.23	26%	8%	11%
SMUD	3.84	0.62	39%	22%	29%
SCE	3.64	0.59	45%	21%	28%
SDGE	3.35	0.54	45%	19%	26%
PGE	3.22	0.52	40%	18%	25%

Next Steps

- Complete FLEXLAB testing
  - Aug – Dec 2016
- Validate savings, assess M&V approaches, package test results (Fall 2016 – Spring 2017)
- M&V protocols, assessment methods (Fall 2016 – Spring 2017)
- Complete assessment method and implementation guidance (Spring 2017)
- Training and tech support for program implementation (through Fall 2017)



Web: cbs.lbl.gov/beyond-widgets-for-utilities

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