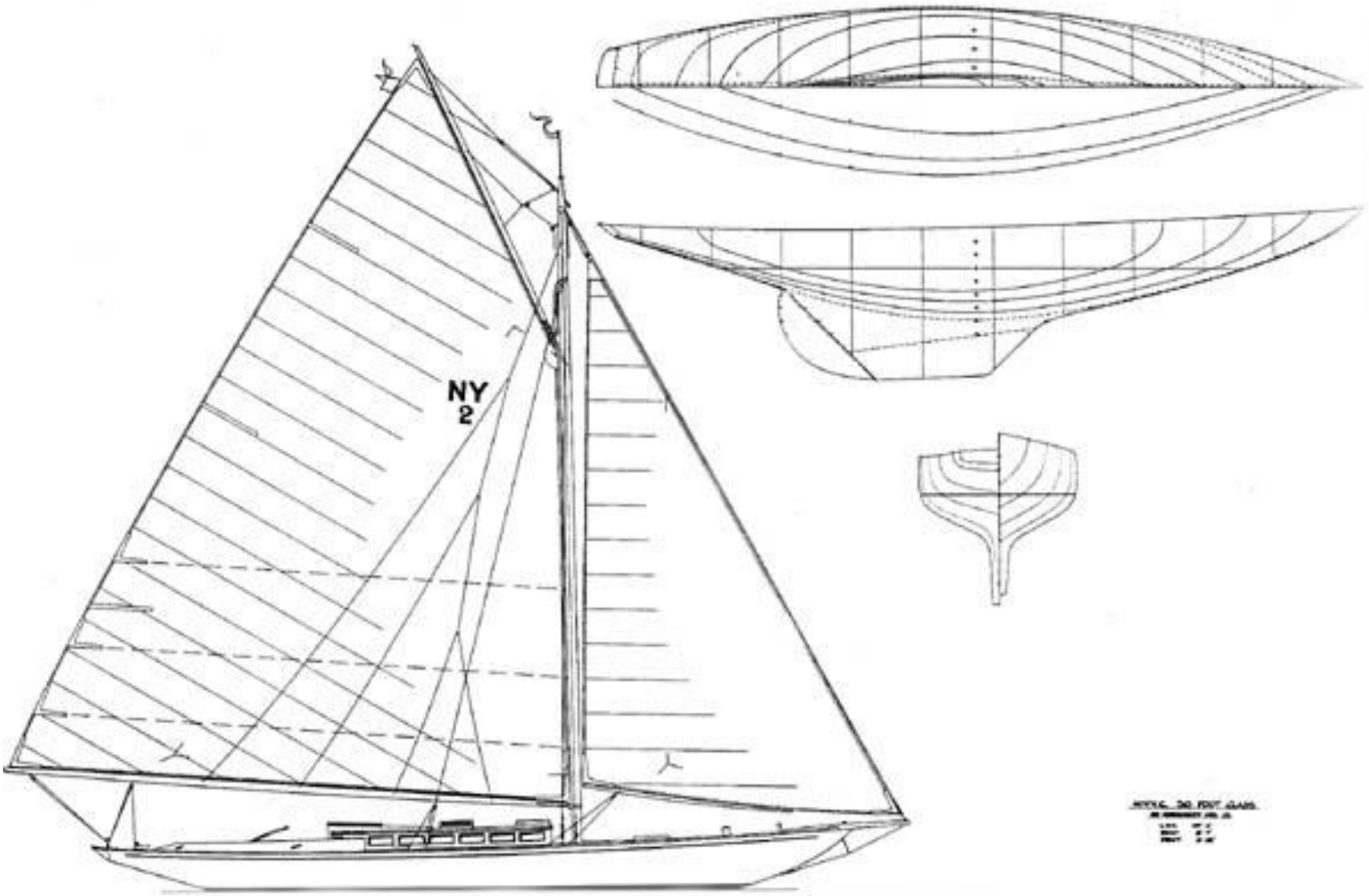
Operational Performance for ZNE Buildings

Jim Kelsey PE BEAP
President, kW Engineering

kW ENGINEERING


NY
2

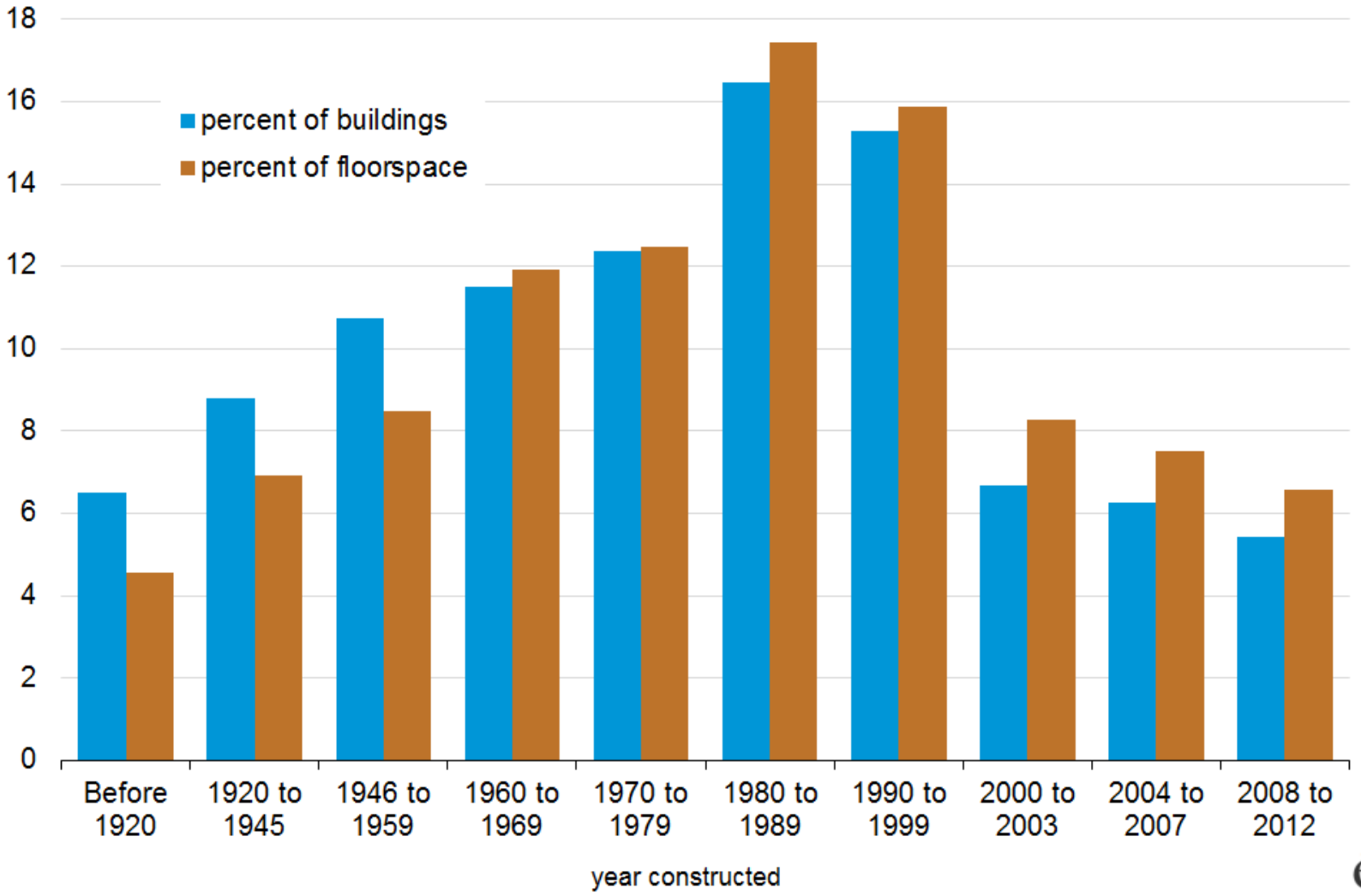
Ahh the dream…

“my she was yar”

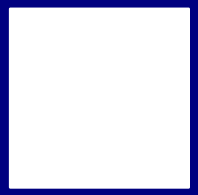

DAMFINO

Life of commercial buildings

Figure 3. About half of all commercial buildings were constructed before 1980

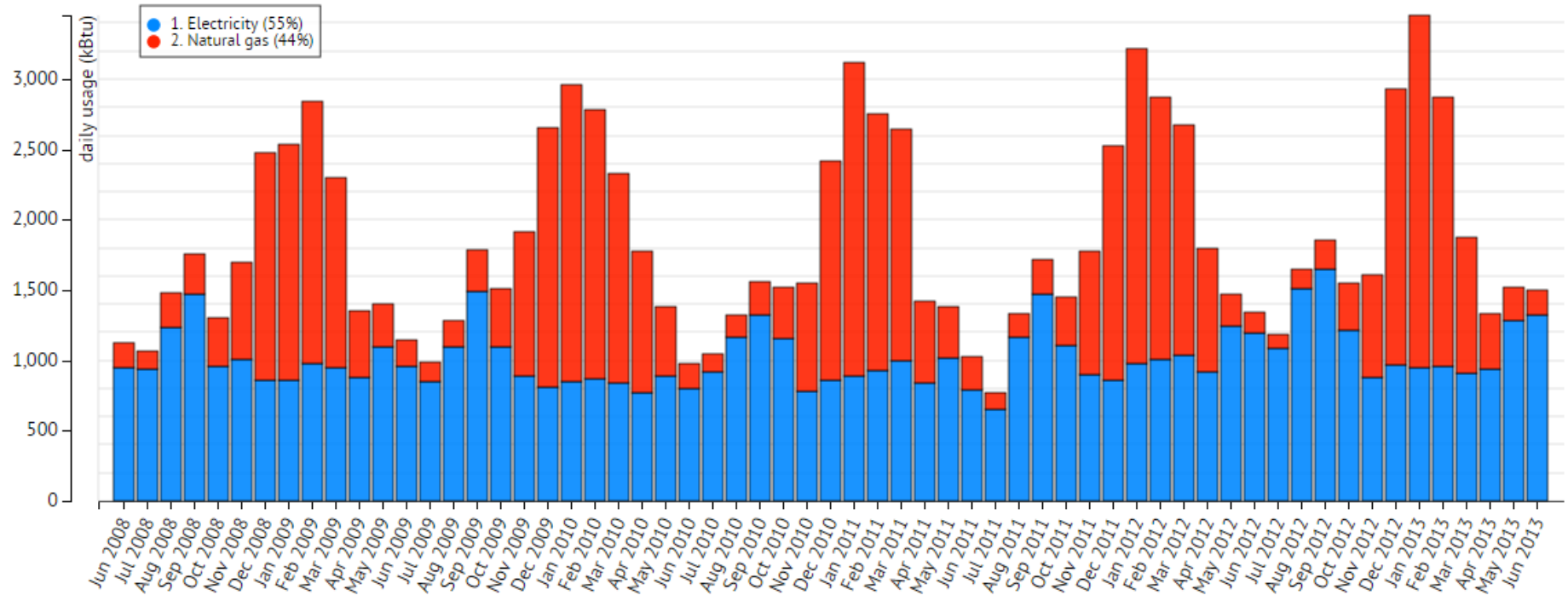


Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey



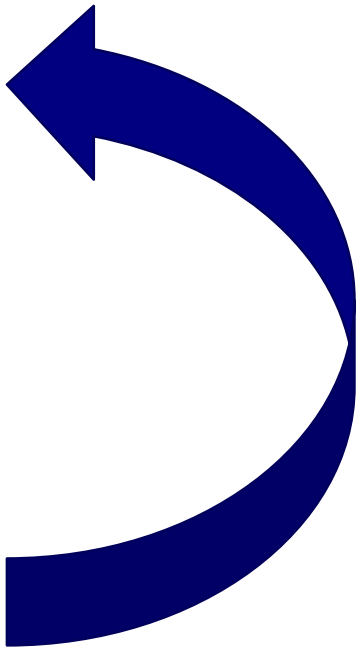
Creep

example school – I didn't even have to look hard…



Recommended Steps

1. Establish role for monitoring performance
2. Budget for integrated design;
   Include Operations Staff in Design Process
3. Utilize simplicity in controls
4. Commission effectively
5. Train site staff
6. Monitor and report performance
   (energy, comfort, IEQ)
7. Engage occupants
8. Make corrections as you go



1. Establish a role for monitoring performance

“when it’s everybody’s job, it’s nobody’s job”

2. Include Operations Staff in Design*

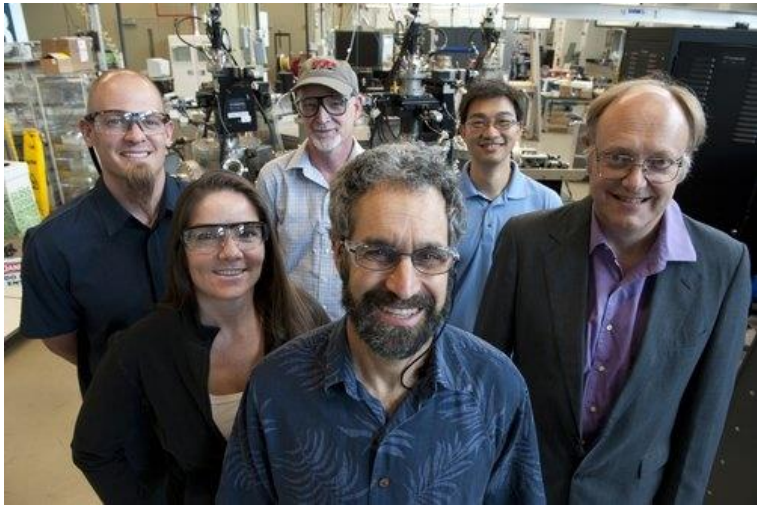
- “I was never consulted”
- “nobody asked me”
- “I could have told them…”
- “The design didn’t allow for…”

example:

- Maintenance
- Access
- Expansion

* I.e. include budget for them to participate – set expectations

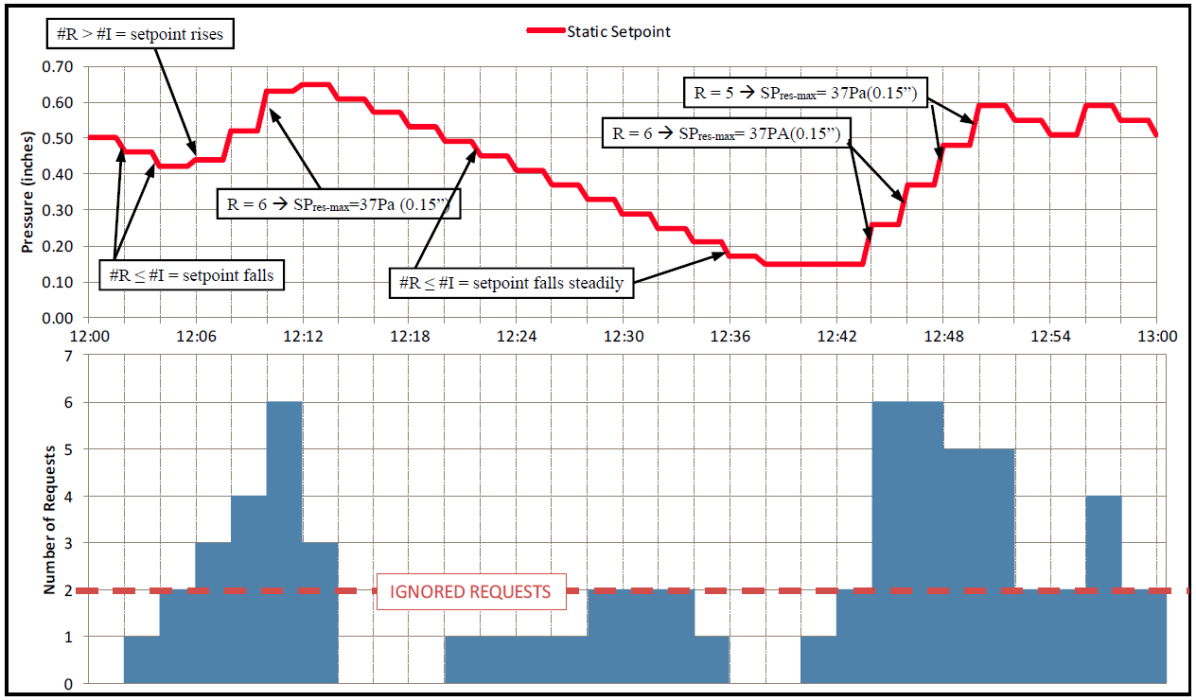
Build a Balanced Team



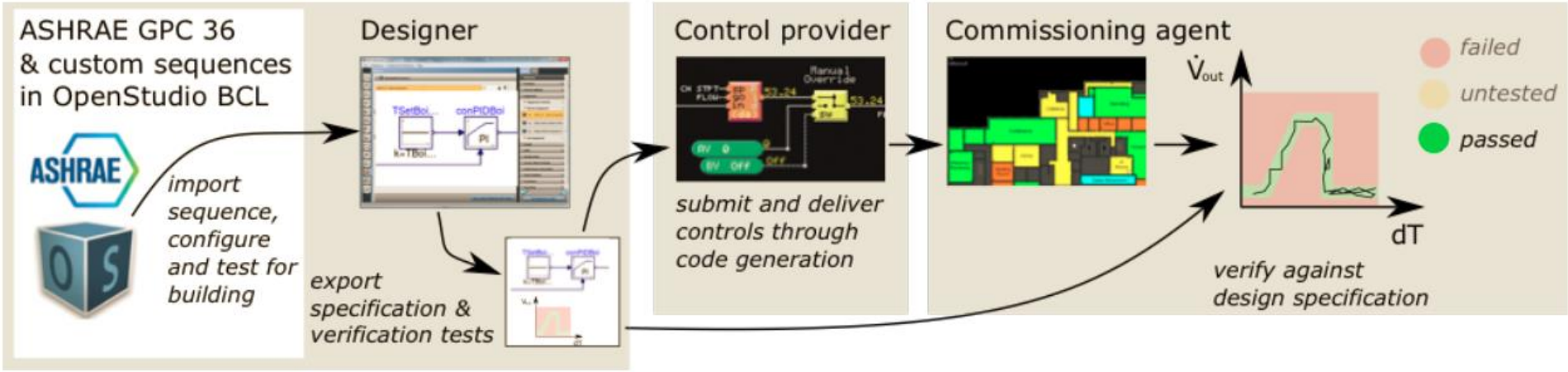
- Committed management
- Engaged financial staff who understand risks and rewards
- Trained building engineers
- Trusted contractors and vendors
- Utility account representatives
- Engaged and informed building occupants
- Trained and experienced design and Cx team

3. Simplicity in Controls Specs

- ASHRAE Guideline 36; “best in class” control sequences
- Heating and cooling plant, hydronic, radiant
- Includes points list and schematics
- Already available as a “drop in” from vendor(s)



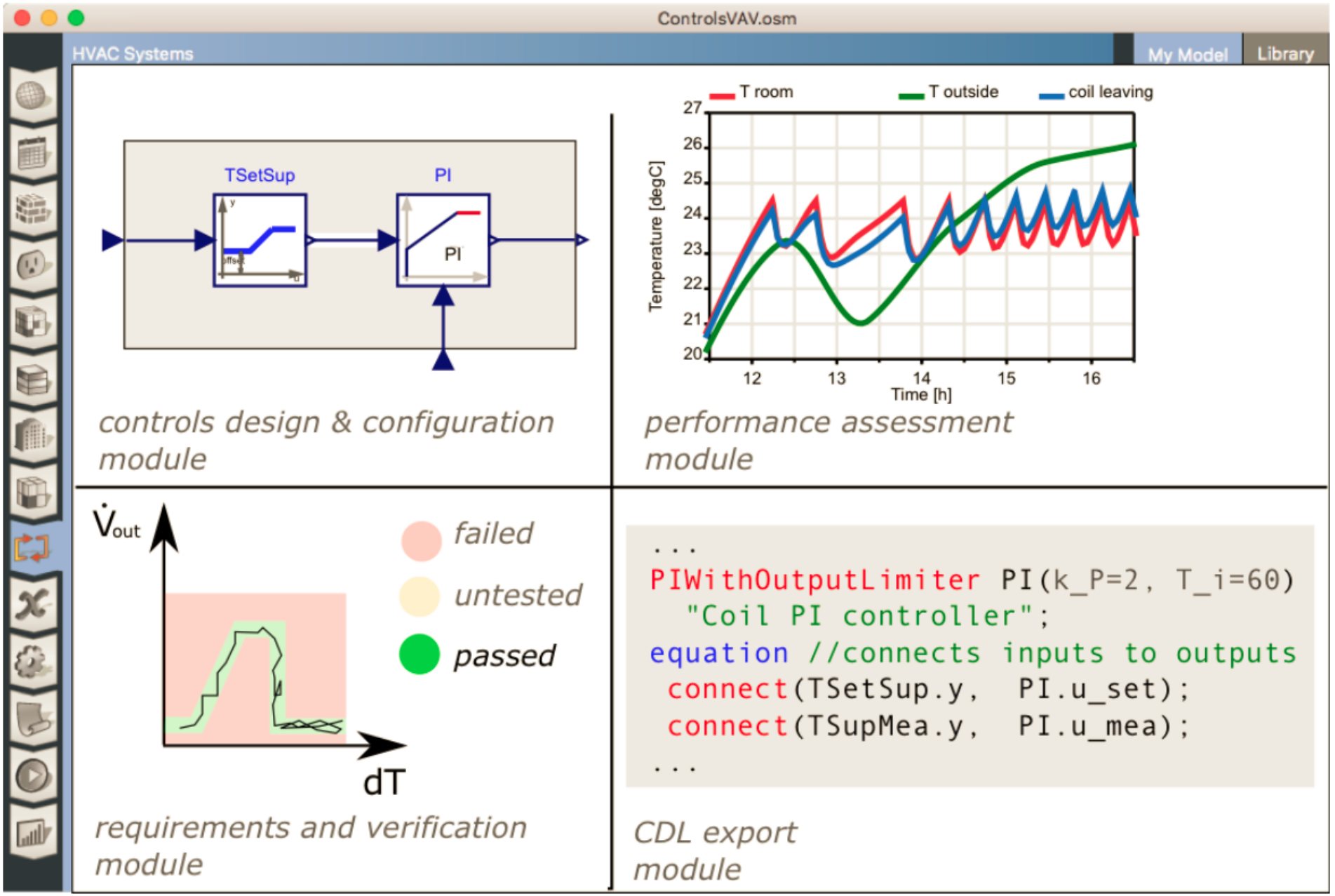
Current research to improve controls implementation



Project Title:

OpenBuildingControl: Performance Evaluation, Specification, and Verification of Building Control Sequences

Integrated design and implementation of building controls


ControlsVAV.osm
HVAC Systems
My Model
Library
TSetSup
PI
PI
controls design & configuration module
T room
T outside
coil leaving
Temperature [degC]
Time [h]
performance assessment module
failed
untested
passed
dT
requirements and verification module
...
PIWithOutputLimiter PI(k_P=2, T_i=60)
"Coil PI controller";
equation //connects inputs to outputs
connect(TSetSup.y, PI.u_set);
connect(TSupMea.y, PI.u_mea);
...
CDL export module

4. Commission Effectively

"The expectation of owners and users should be that post-occupancy commissioning should continue for at least two seasons, so that there is adequate time for a thorough "shake-out" of the operating systems "

Zero Net Energy Case Study Buildings *Volume 1,* Edward Dean, FAIA Bernheim + Dean, Inc. Foreword by Peter Turnbull, Principal, Commercial Buildings, Pacific Gas and Electric Company, *September 2014.*


Fan
AUTO
ON
Manual

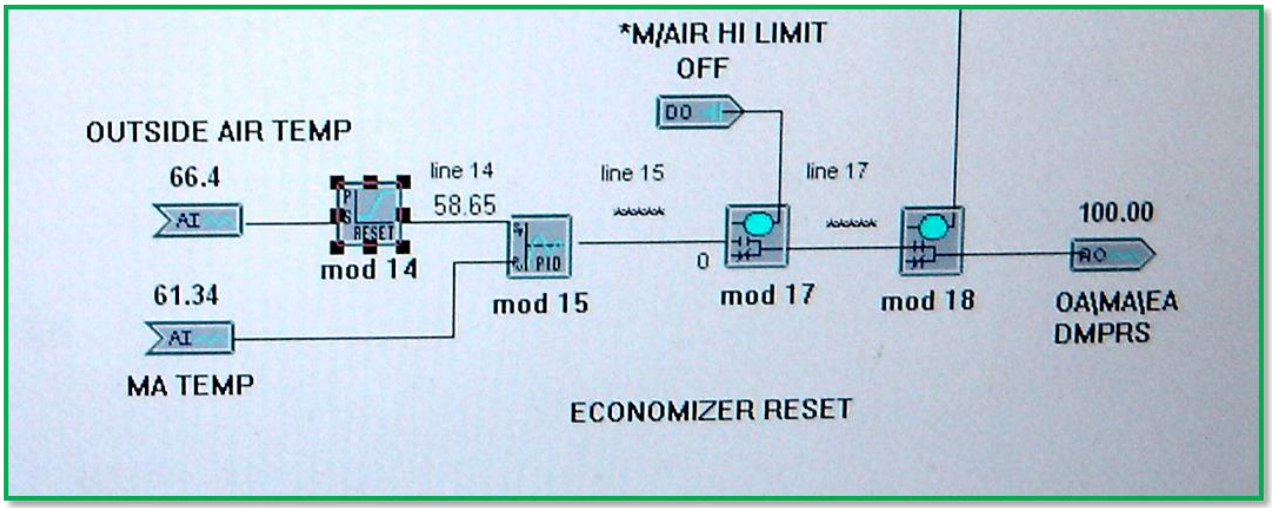
Commission PV

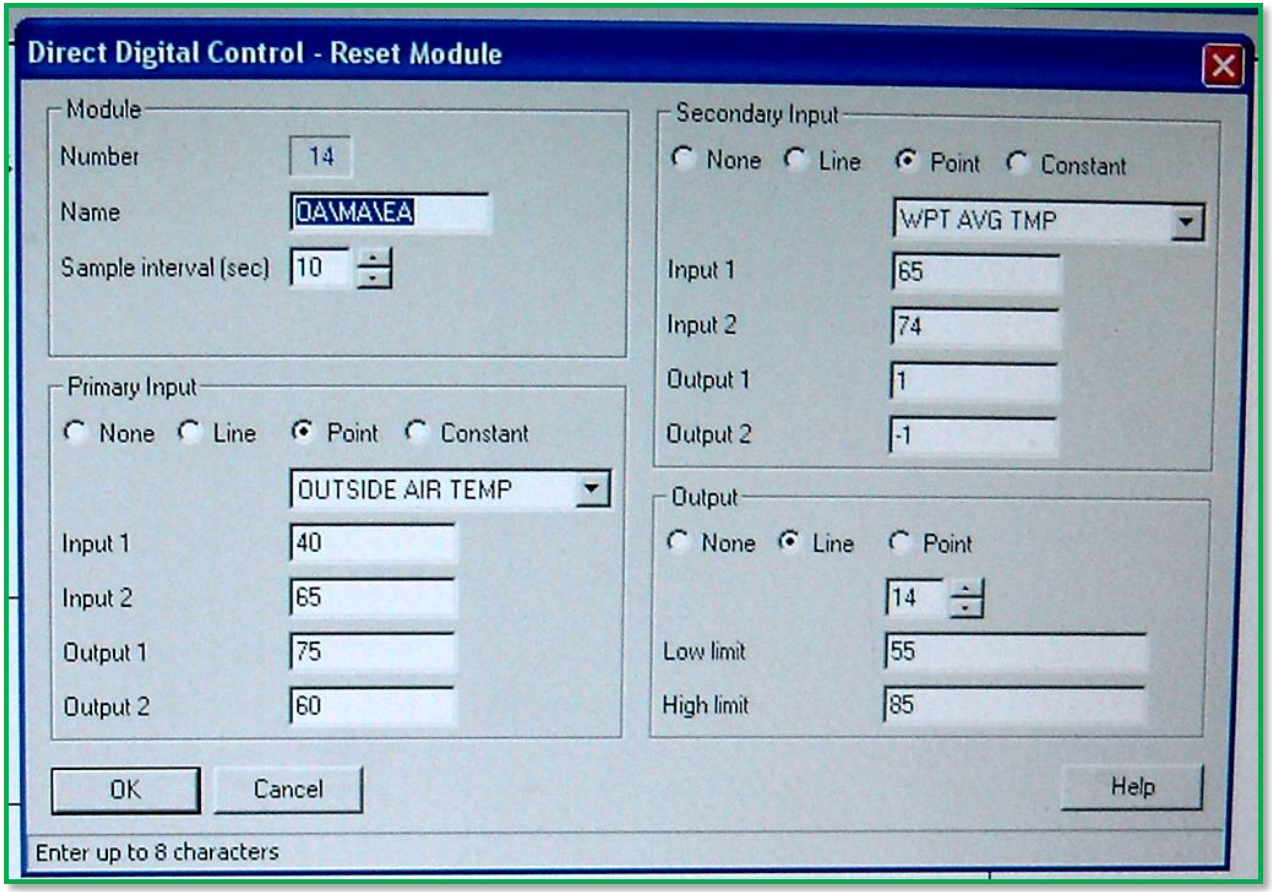

ABB
S 282 UC
K 40 A
ON
OFF
AC
connect
DC
Disconnect
Now
Day
Year
Total
Setup
2206W
Ground
Fault
Electric Shock Hazard.
CAUTION
For continued protection against risk of fire,
replace only with same type and rating of fuse
GFDI FUSE 1A/600V


ON
OFF
AC Disconnect
DC Disconnect
Now
Day
Year
Total
Setup
STATE
40
Ground Fault
PHOTOVOLTAIC DISCONNECT
- WARNING -
Electric Shock Hazard.
Do not touch terminals. Terminals on both line and load side may be energized in open position.
CAUTION
For continued protection against risk of fire, replace only with same type and rating of fuse
GFDI FUSE 1A/600V
Dubl-Nature
BAY WEST

5. Train

- If operators understand the plan they can make the best use of controls
- Go beyond manufacturers training – system approach



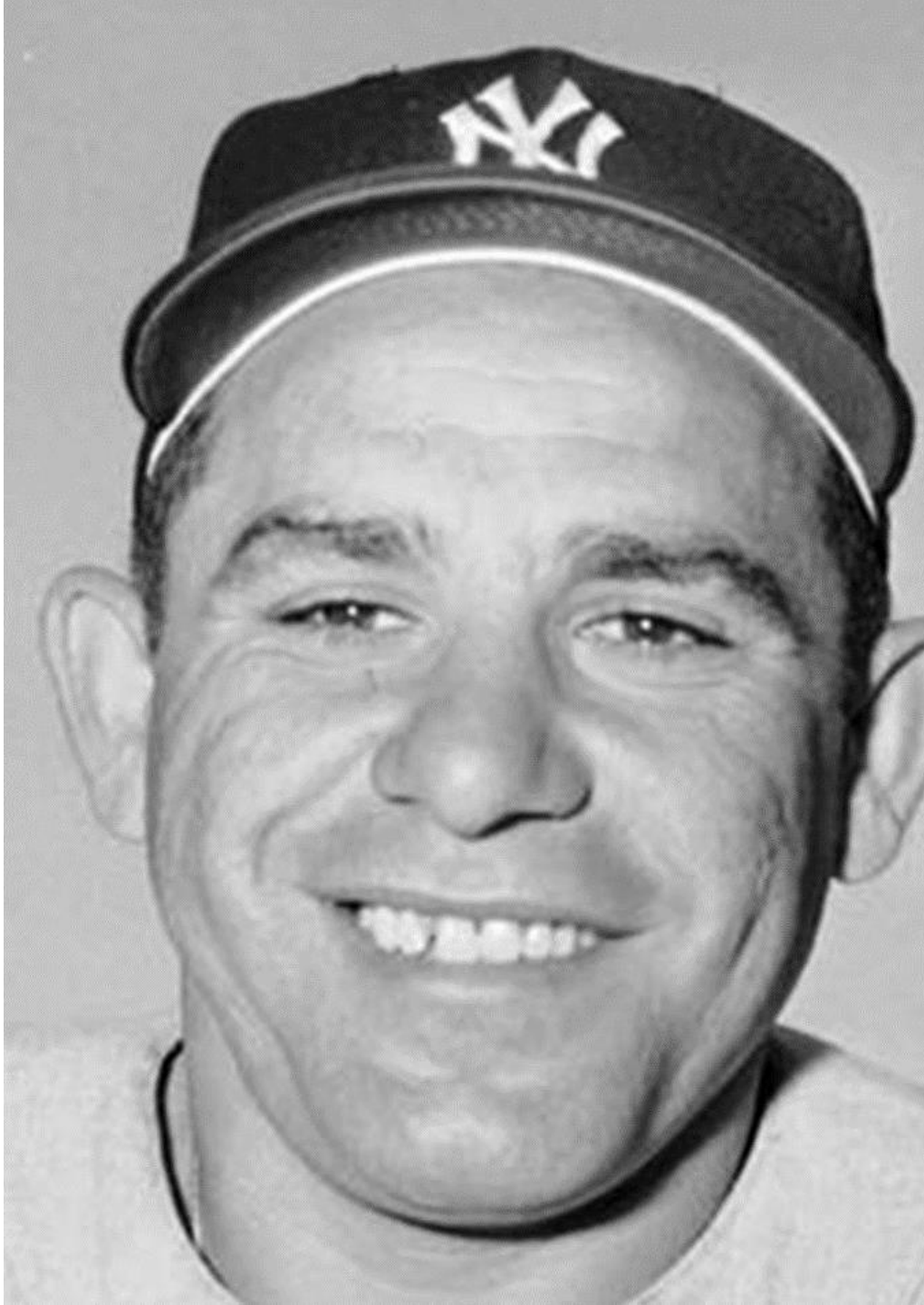


6. Monitor & Report Performance

Good News

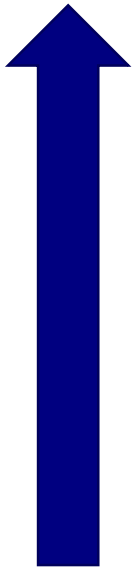
"The future ain't what it used to be."

- Yogi Berra



Energy Management Information Systems – Broad Types

- FDD, anomaly detection
- Sub-metering
- Portfolio
- Building over time



Micro

Macro

Increasing:

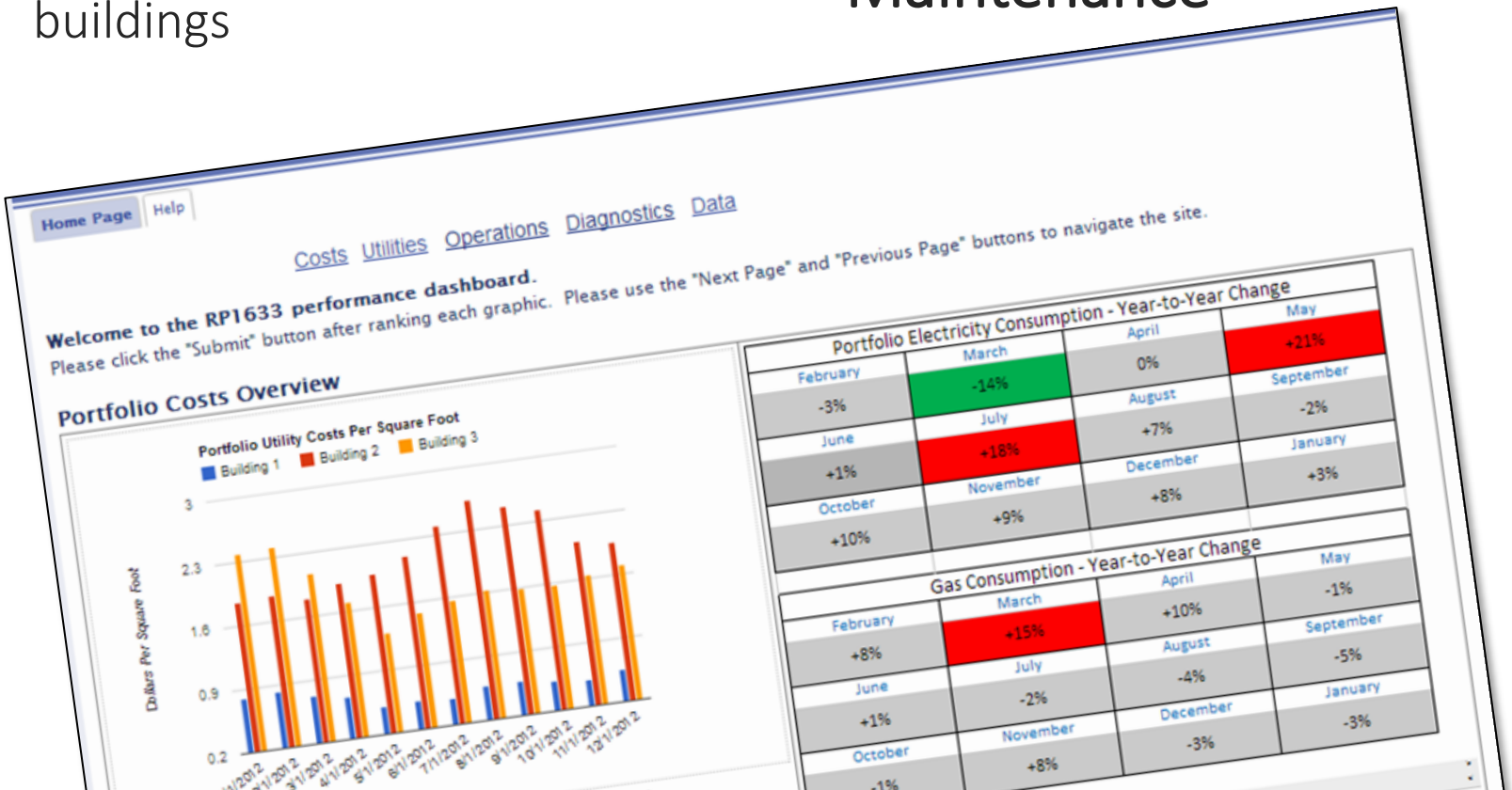
- Detail
- Complexity
- Cost

"Put meters clearly on plans and in specs"
- John Elliott, CSO, LBNL

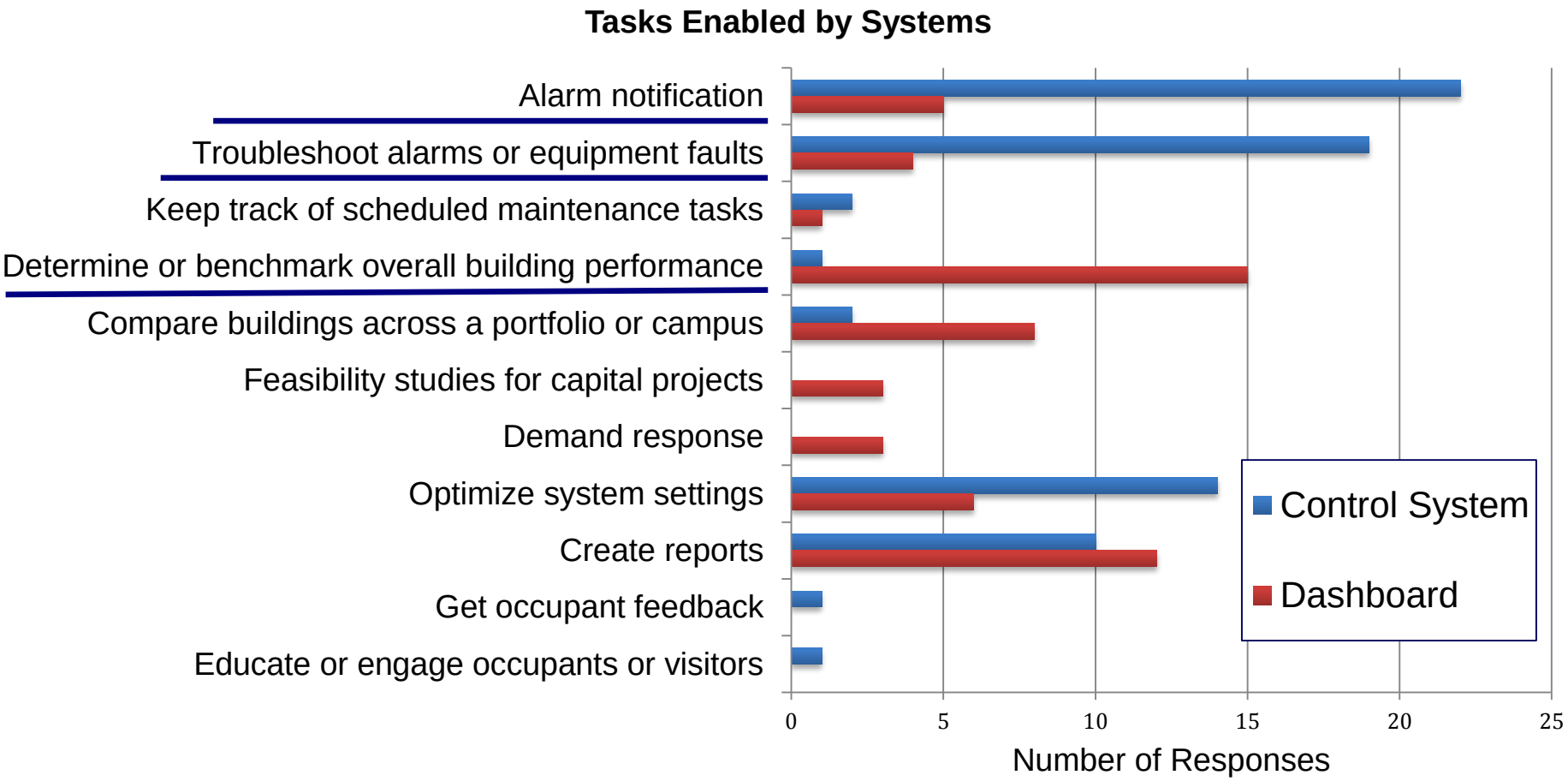
ASHRAE Research Project RP 1633

- Seeks to find what kinds of tools building operators and management like / use
- Detailed surveys in about 40 buildings

Title: Data and Interfaces for Advanced Building Operations and Maintenance

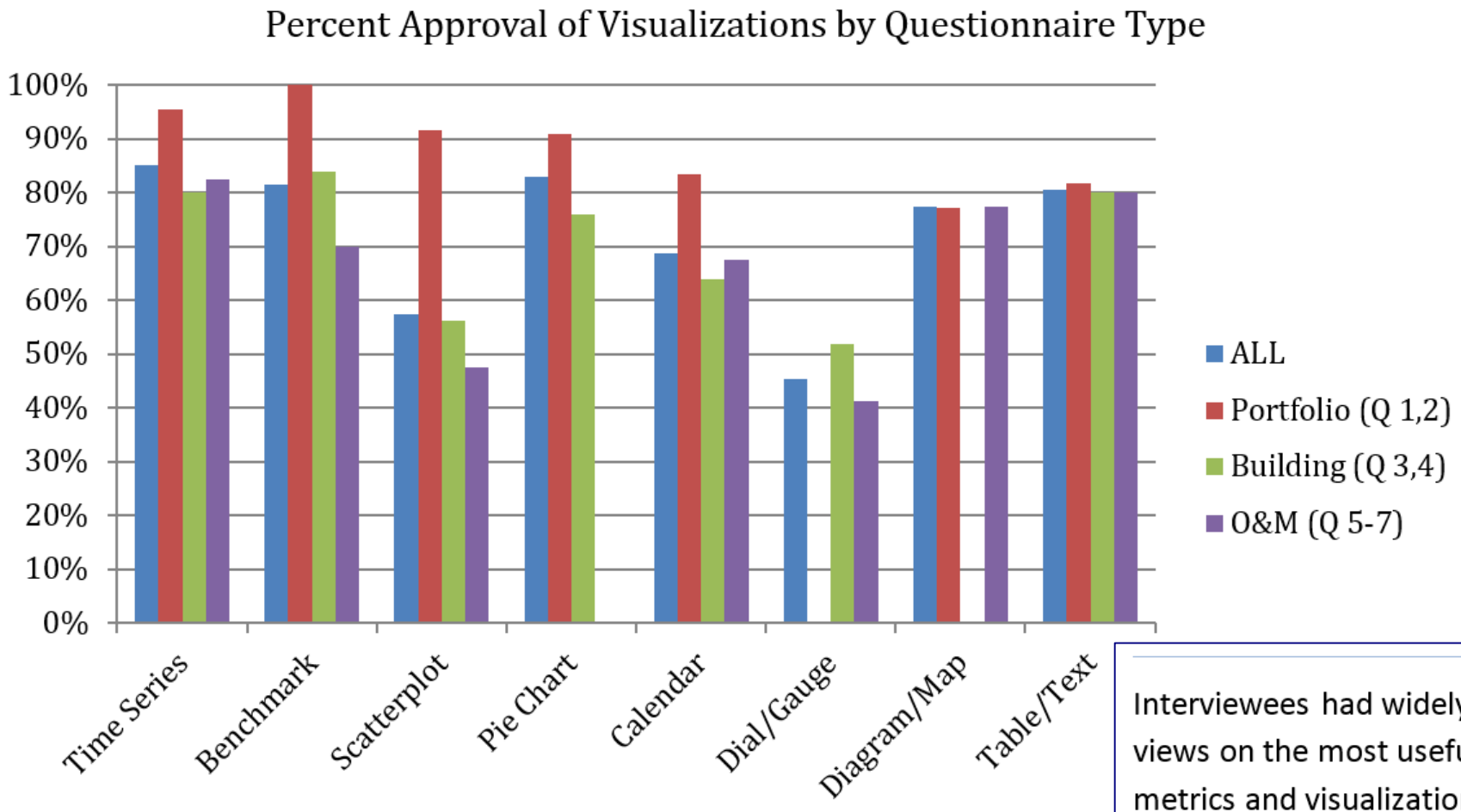


RP 1633 Results



Results from ASHRAE RP 1633: Effective Metrics

- Operating costs, energy and water costs, energy and water consumption, peak demand, and greenhouse gas emissions
- Normalize by area, weather, compare buildings to each other, and compare to benchmarks (e.g. Energy Star).
- Time-series charts and pie charts showing the contribution of each building or utility to the total are recommended.
- Overlaying whole building metrics, especially energy use intensity, on color-coded campus maps draws attention to outliers.
- O&M personnel appreciated the value of color-coding maps with whole building operating statistics and diagnostic metrics.
- Important to be able to drill down into information



The difference in ranking among the top 20 [visualizations] is very small, ranging from a score of 2.5 to 3.07, while the full rankings ranged from 1.44 to 3.07

Interviewees had widely varying views on the most useful metrics and visualizations, and it was clear that an inflexible, fixed set of metrics and visualizations would not serve the needs of all stakeholders.

RP 1633 Results – less clear

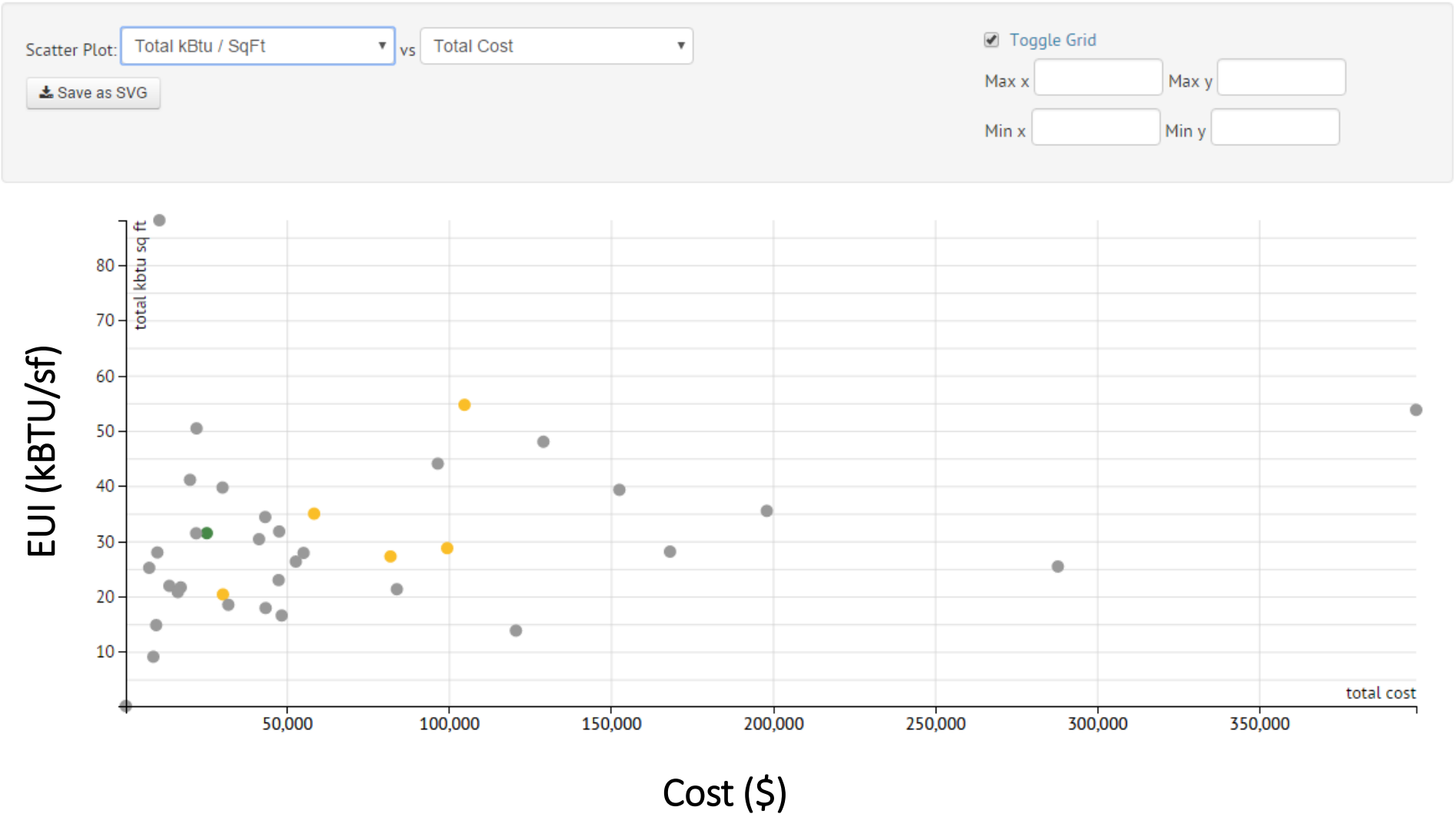
E.g. the highest-ranked metric

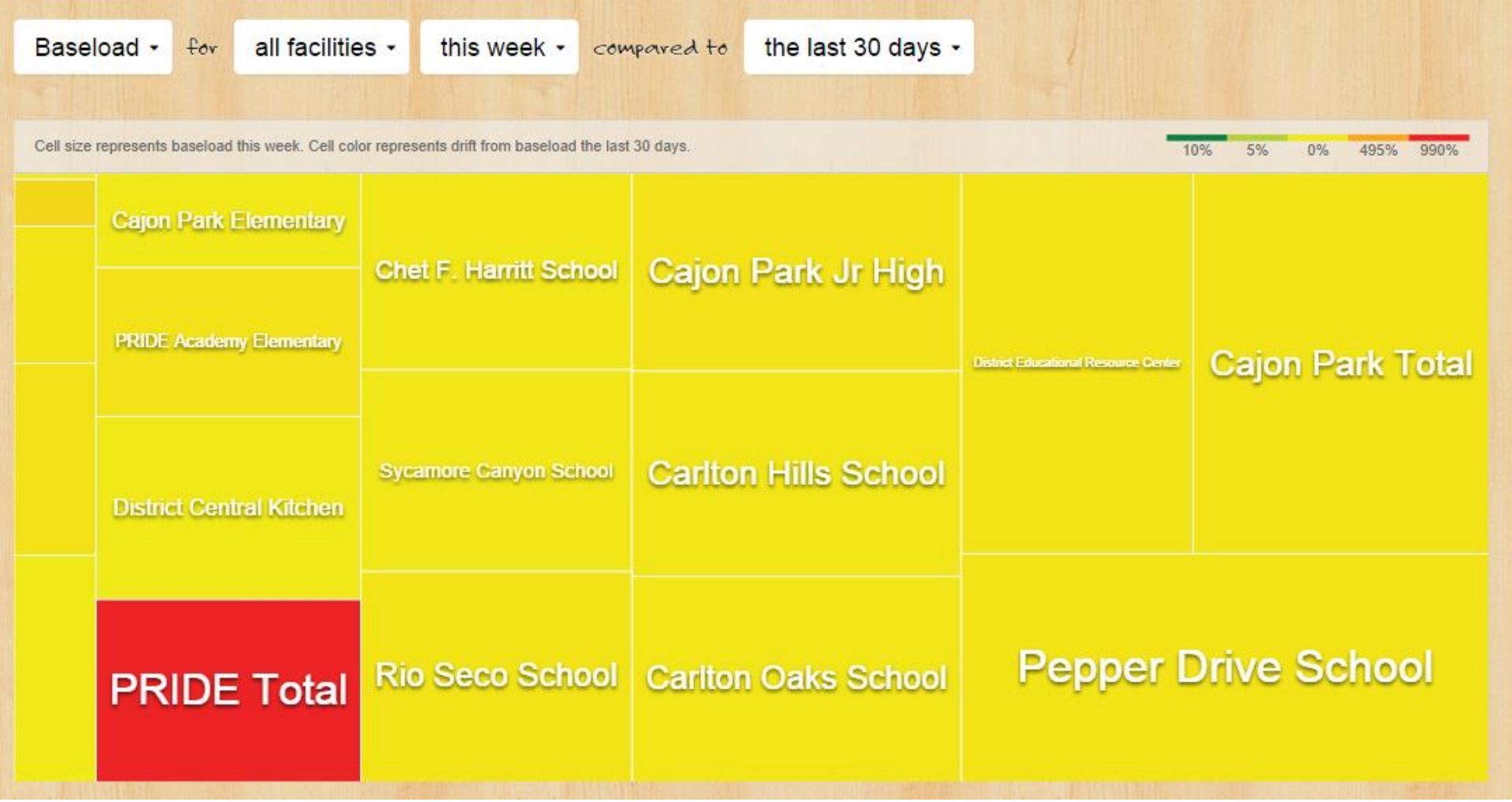
Building	Size (ft^2)	% of Portfolio SQF
Building 1	463,249	45.62%
Building 2	418,663	41.23%
Building 3	133,552	13.15%
Whole Portfolio	1,015,464	-

2012 Expenditures	Cost	% of Expenditures
Total Operations and Fixed Expenditure	$8,854,846	100.00%
Maintenance	$1,086,546	12.27%
Utilities	$2,538,660	28.67%
Fixed (ex. Taxes, Insurance, etc.)	$1,523,196	17.20%
Cleaning	$1,421,650	16.06%
Other	$2,284,794	25.80%

"The most popular equipment-level management tools were the time series and tabular raw data."

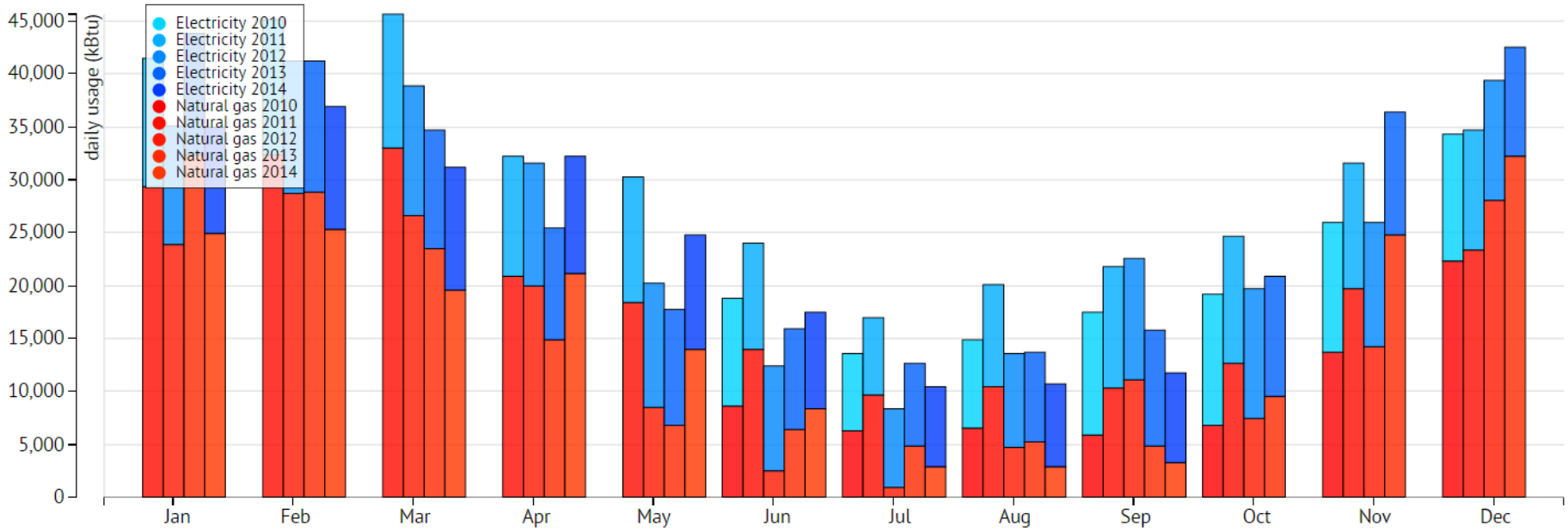
Portfolio examples





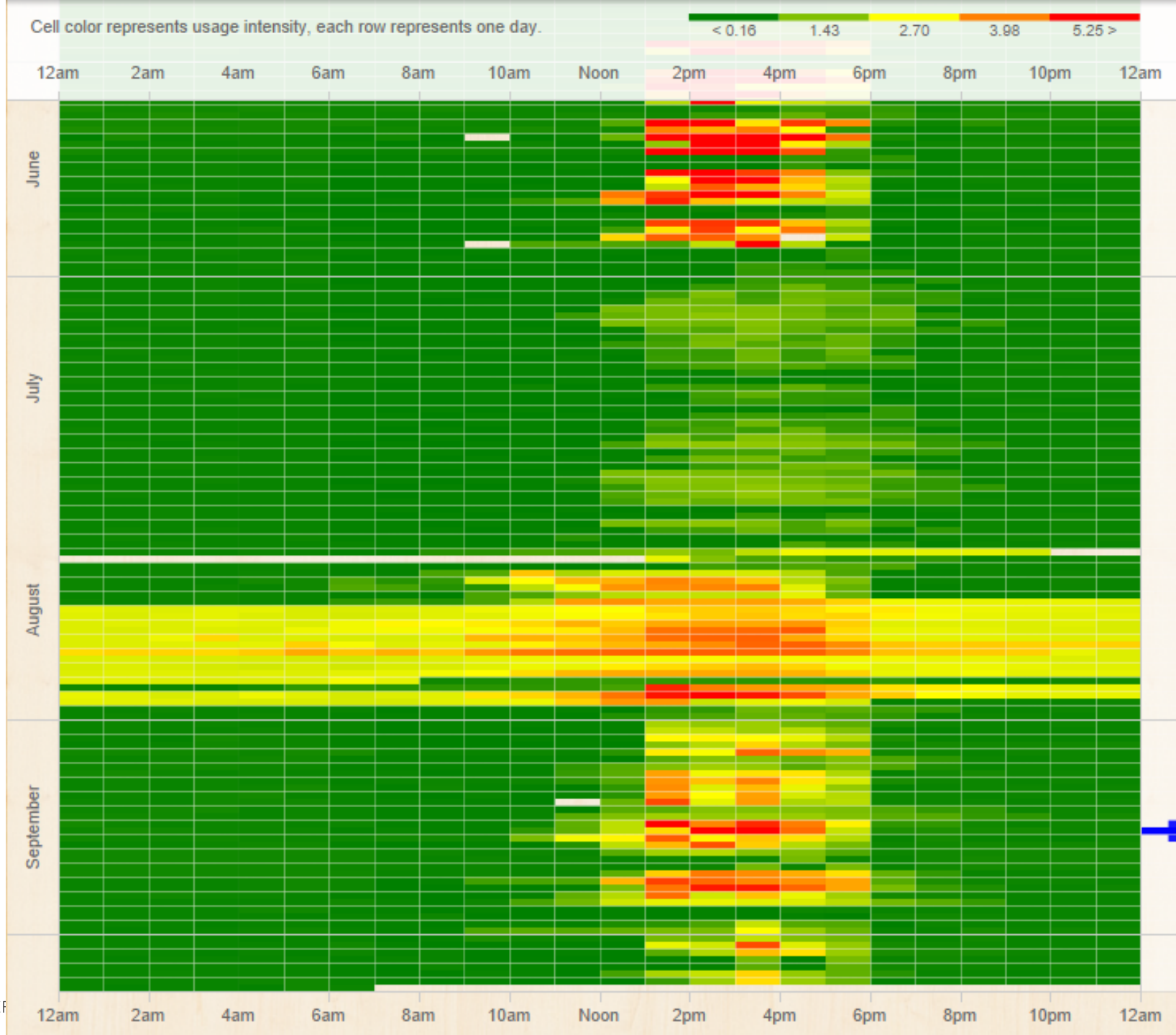
Portfolio examples

Single Buildings



✓ RP 1633

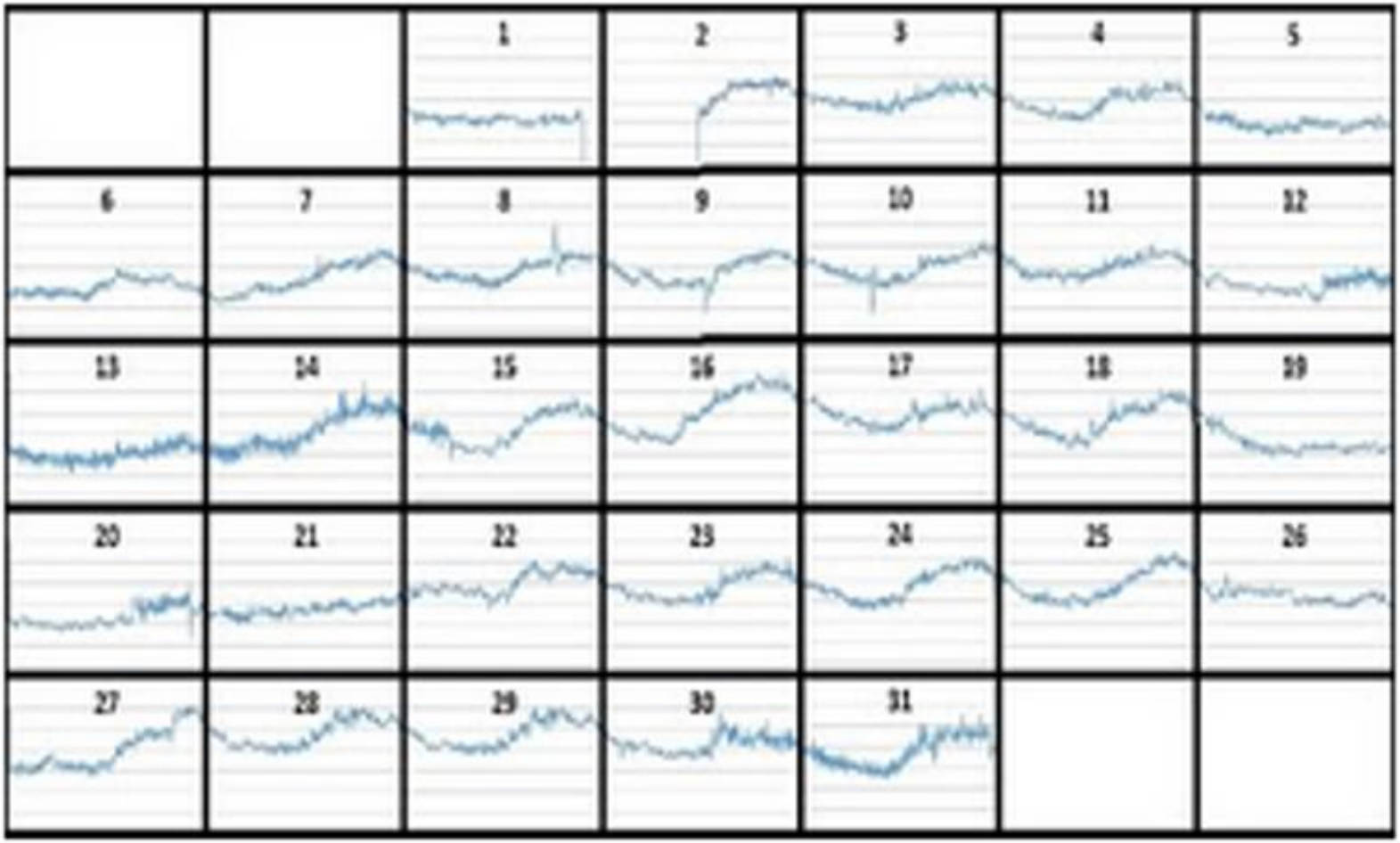
Visualizations
Heat Map



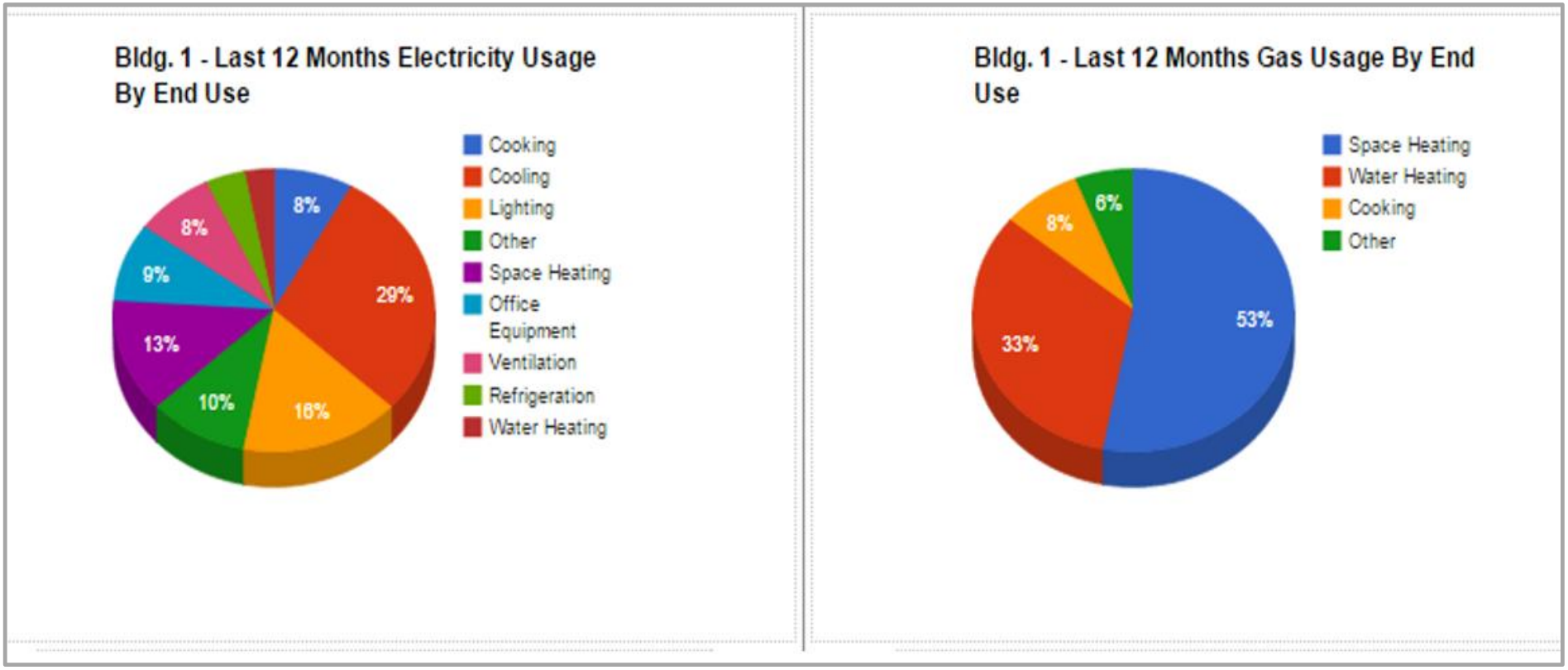
January Electricity Daily Trends (kW)

Building: **Building 1** Building 2 Building 3

Utility: **Electricity** Gas Water

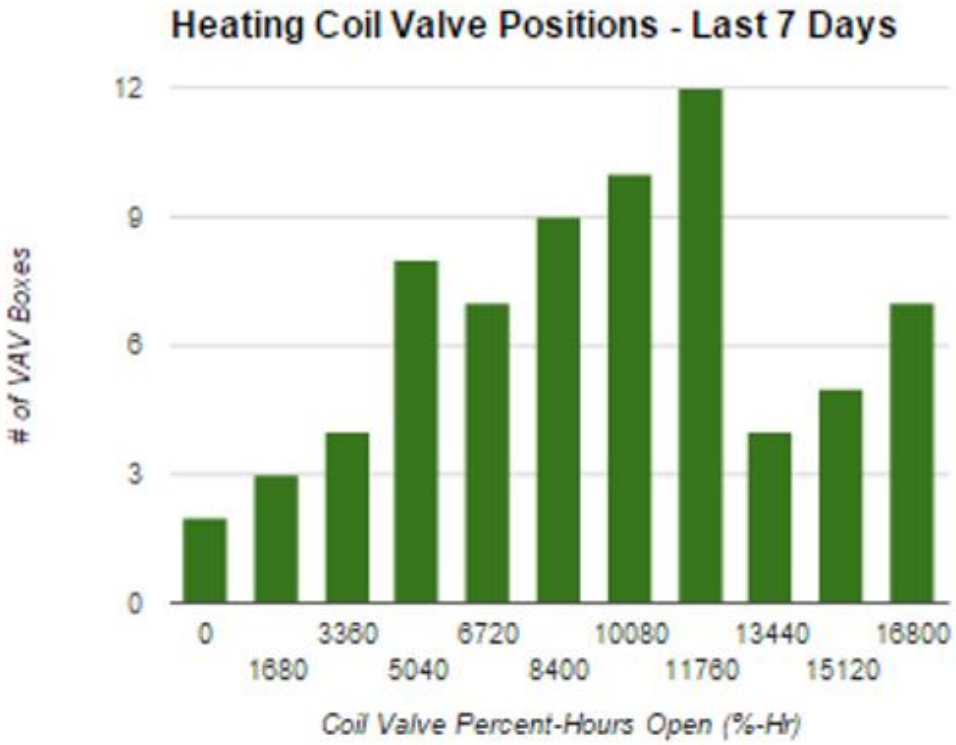


Building Level - Submetering



#1 ranked graph for utility level info

Zone Level Fault Detection

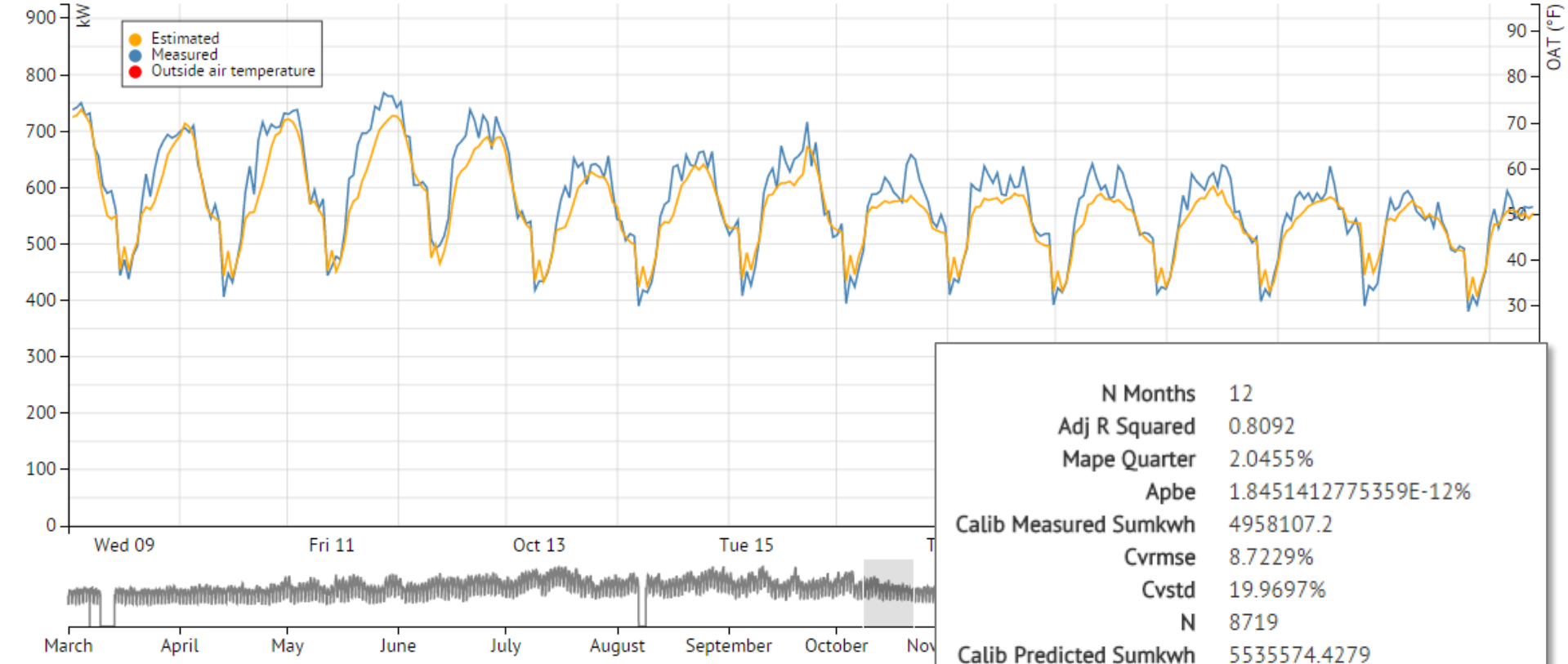


Faults Severity Summary 1/26/13 – 2/1/13 *(0 = No Faults, 5 = High Priority)*

Plant	Sat.	Sun.	Mon.	Tues.	Wed.	Thur.	Fri.
HW Bldg. 1	1	3	5	2	2	1	1
HW Bldg. 2	0	2	3	0	2	0	4
HW Bldg. 3	2	2	0	4	0	1	1
CHW Bldg. 1	1	0	3	5	2	0	0
CHW Bldg. 2	0	0	1	0	0	2	0
CHW Bldg. 3	2	0	1	1	2	3	1

Select a plant to view details

Zone-level: Diagnostic



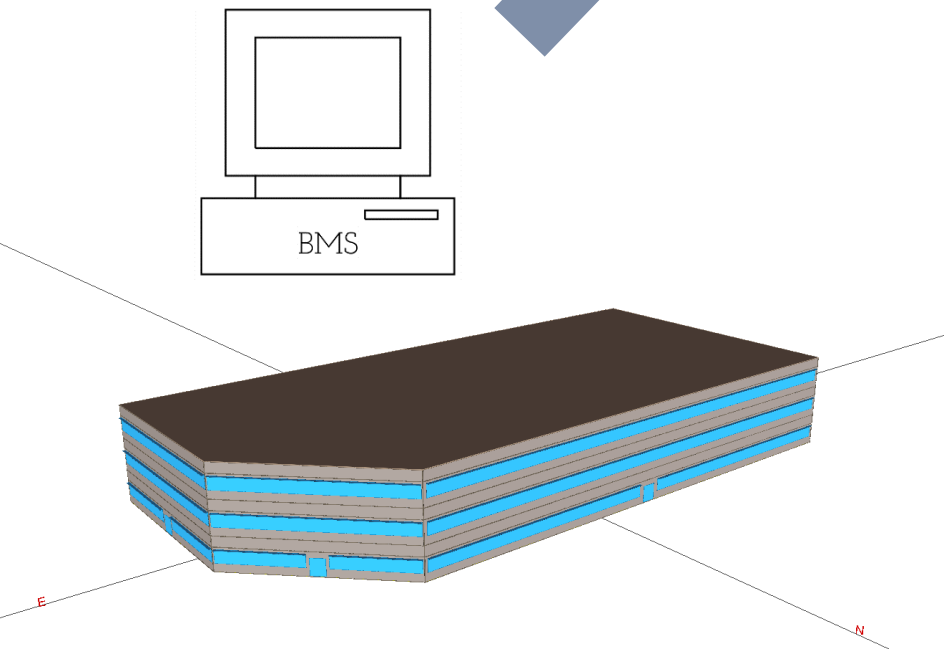
N Months	12
Adj R Squared	0.8092
Mape Quarter	2.0455%
Apbe	1.8451412775359E-12%
Calib Measured Sumkwh	4958107.2
Cvrmse	8.7229%
Cvstd	19.9697%
N	8719
Calib Predicted Sumkwh	5535574.4279
Nrmse Hour	6.9092%
Mape Month	2.3633%
R Squared	0.813
Net Determination Bias	-1.8451412775359E-12%
N Quarters	4
Nrmse Day	4.4987%
Nmbe	-1.8829338481783E-12%

Whole Building

(nice sweet spot for cost and value)

Auto FDD

Automated
Fault Detection &
Diagnostics



Site 1
Excessive Boiler Operation
Excessive Relief Fan Operation
Economizer Malfunction

Site 2
Excessive Relief Fan Operation
Economizer Malfunction

Circuit Level FDD

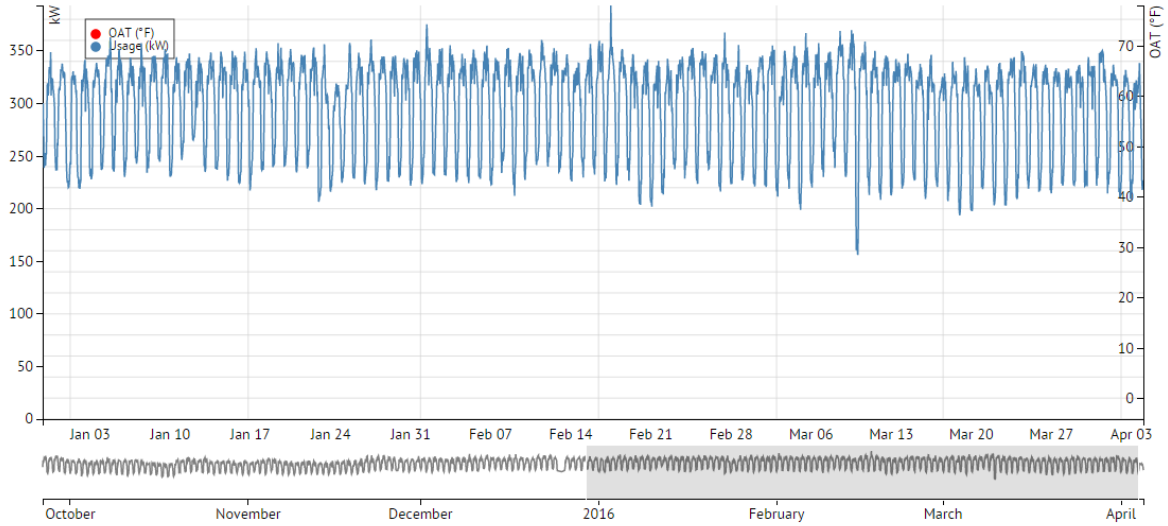
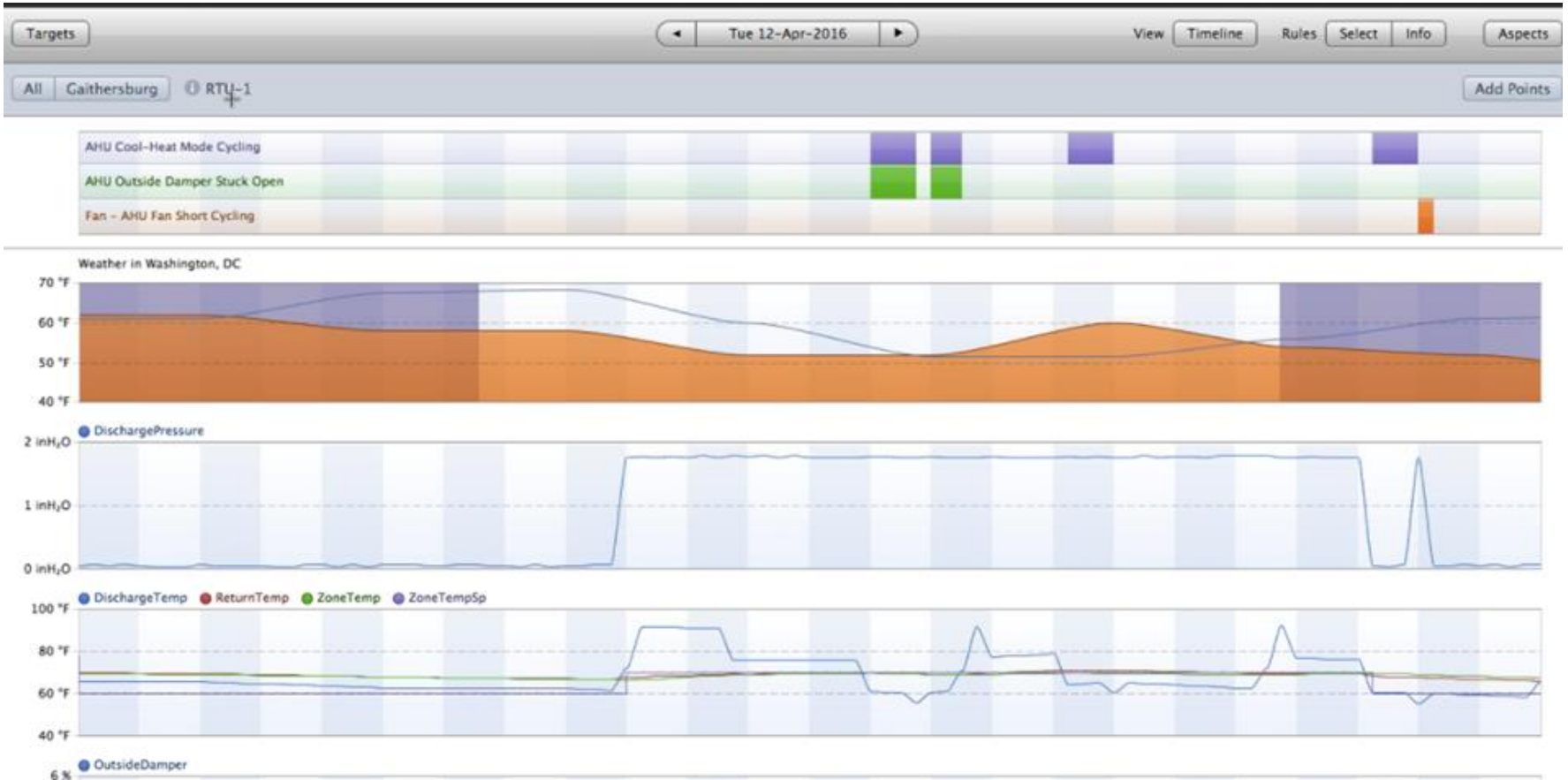


Image Source: Outsmart Inc.

FDD – Sensor Level

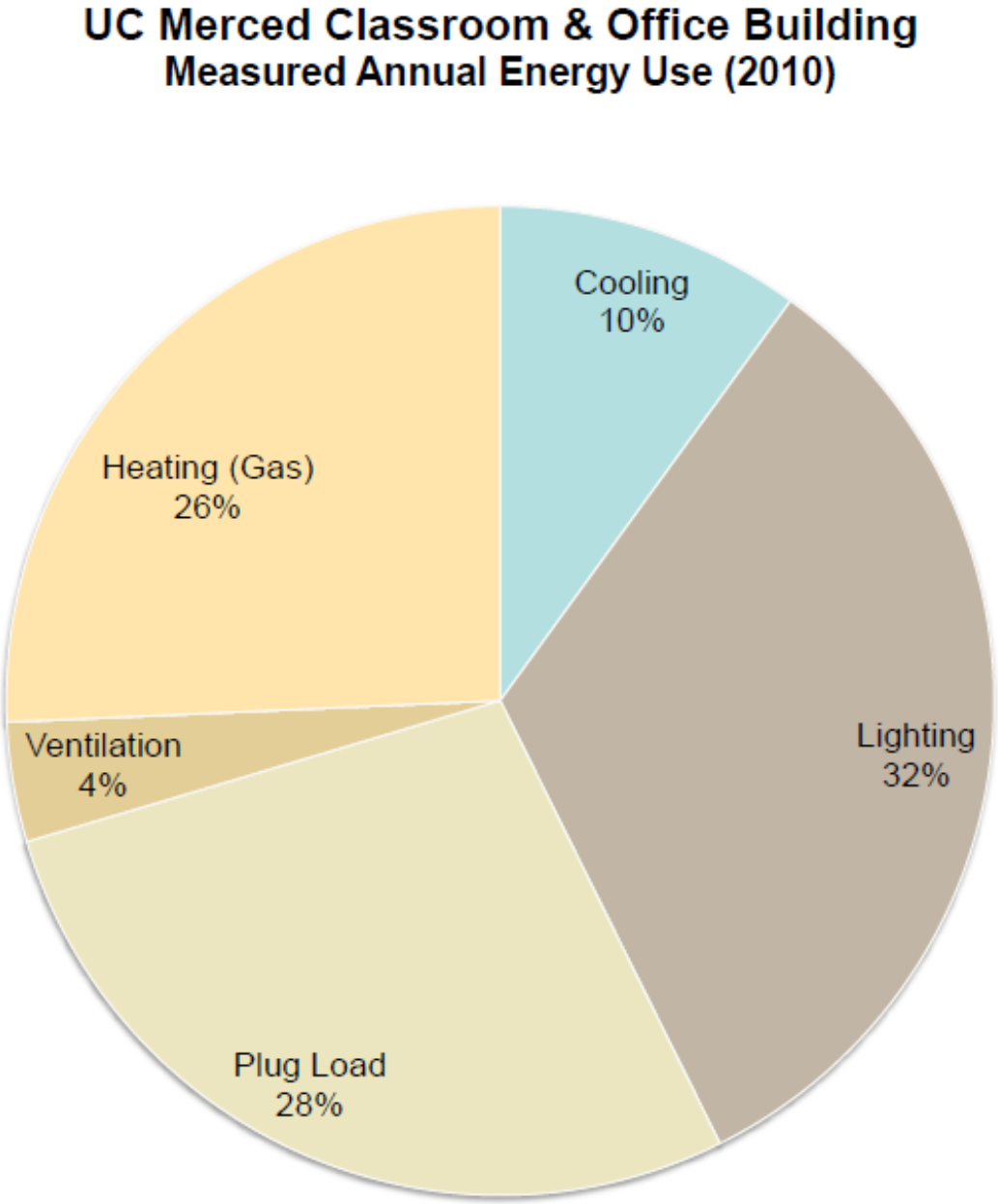
- Integrates with controls platforms
- Tag data to organize
- Run rules to look for issues

Image Source: SkyFoundry



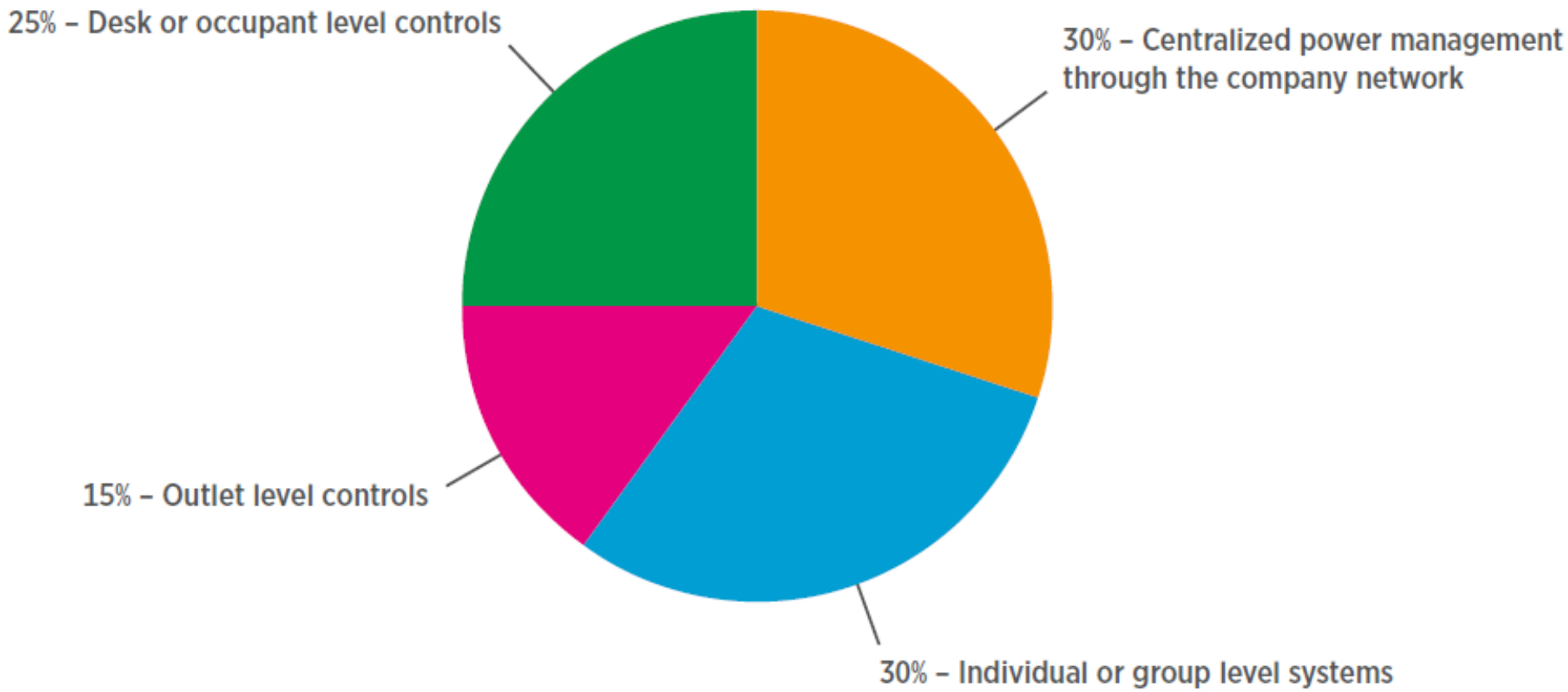
Managing Plug Loads

- Choose best practice
- Sub-meter them
- Control them



Zero Net Energy Case Study Buildings Vol. 1 and 2, Edward Dean, FAIA, Bernheim + Dean, Inc., Foreword by Peter Turnbull, Pacific Gas and Electric Company, Sept. 2014

Types of Controls: Plug Loads



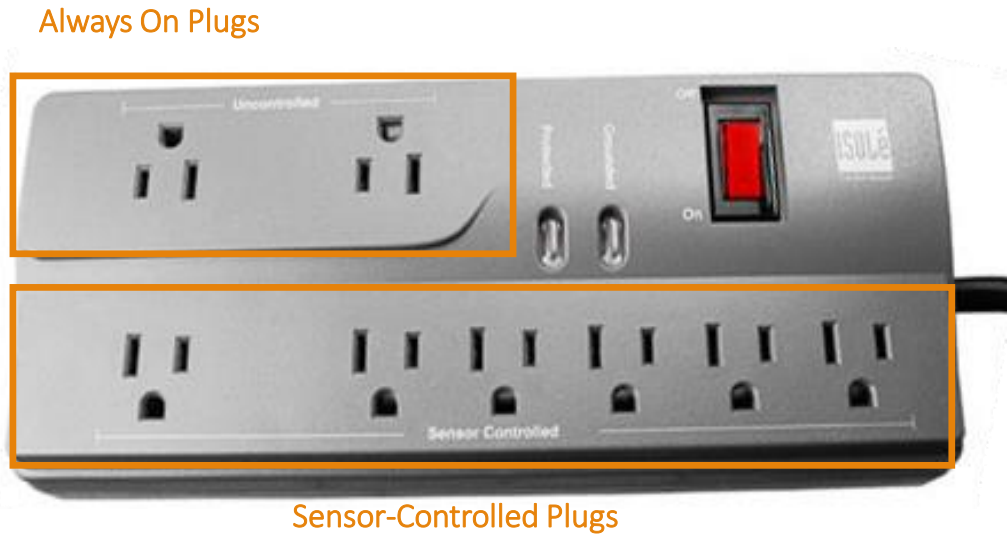
»Most (64%) buildings surveyed use plug load controls or monitoring

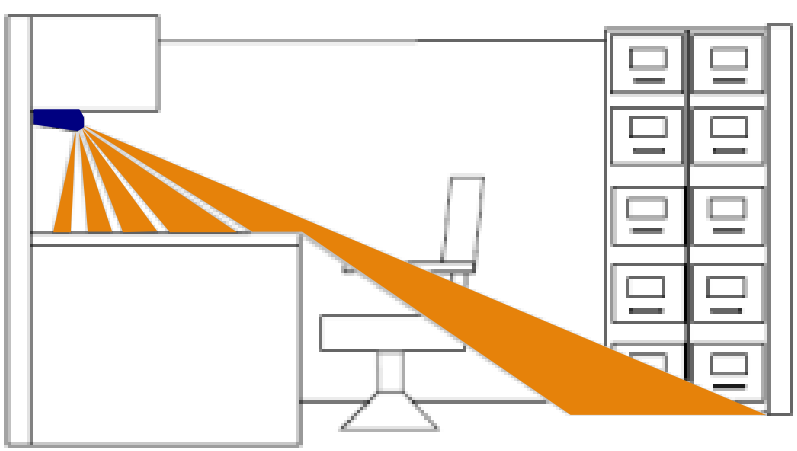
CABA

nbi new buildings institute

Power Strip Occupancy Sensors

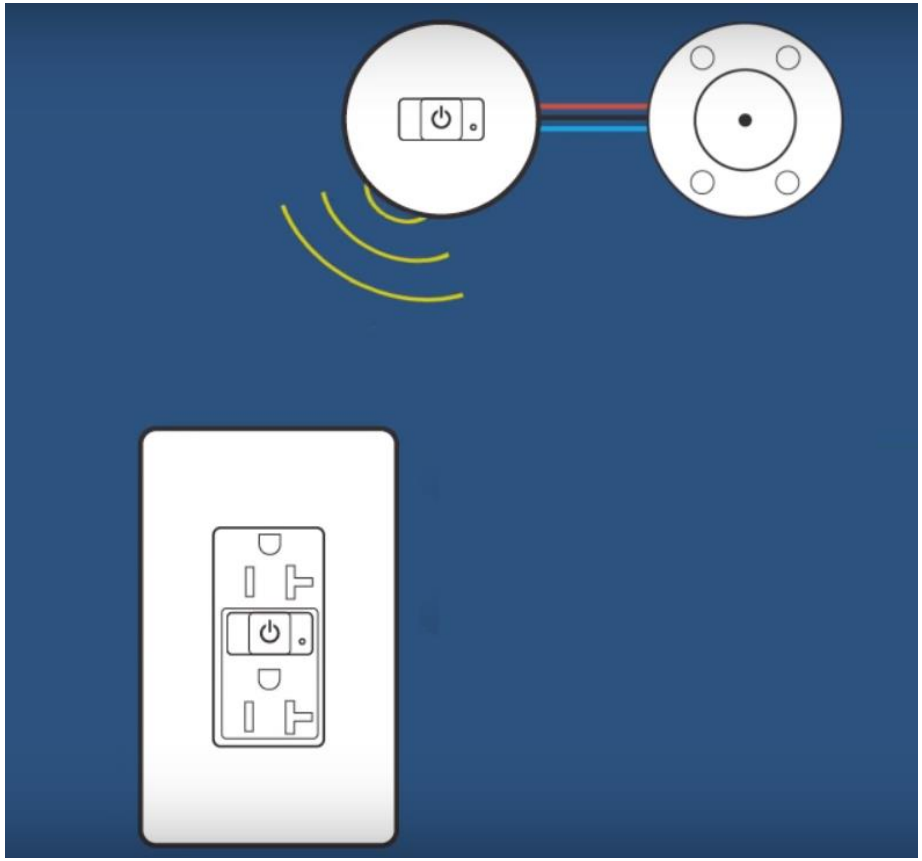
- Reduce operating hours
  - Occupancy sensors
  - Slave plugs to PC
- Costs are approximately $100/unit



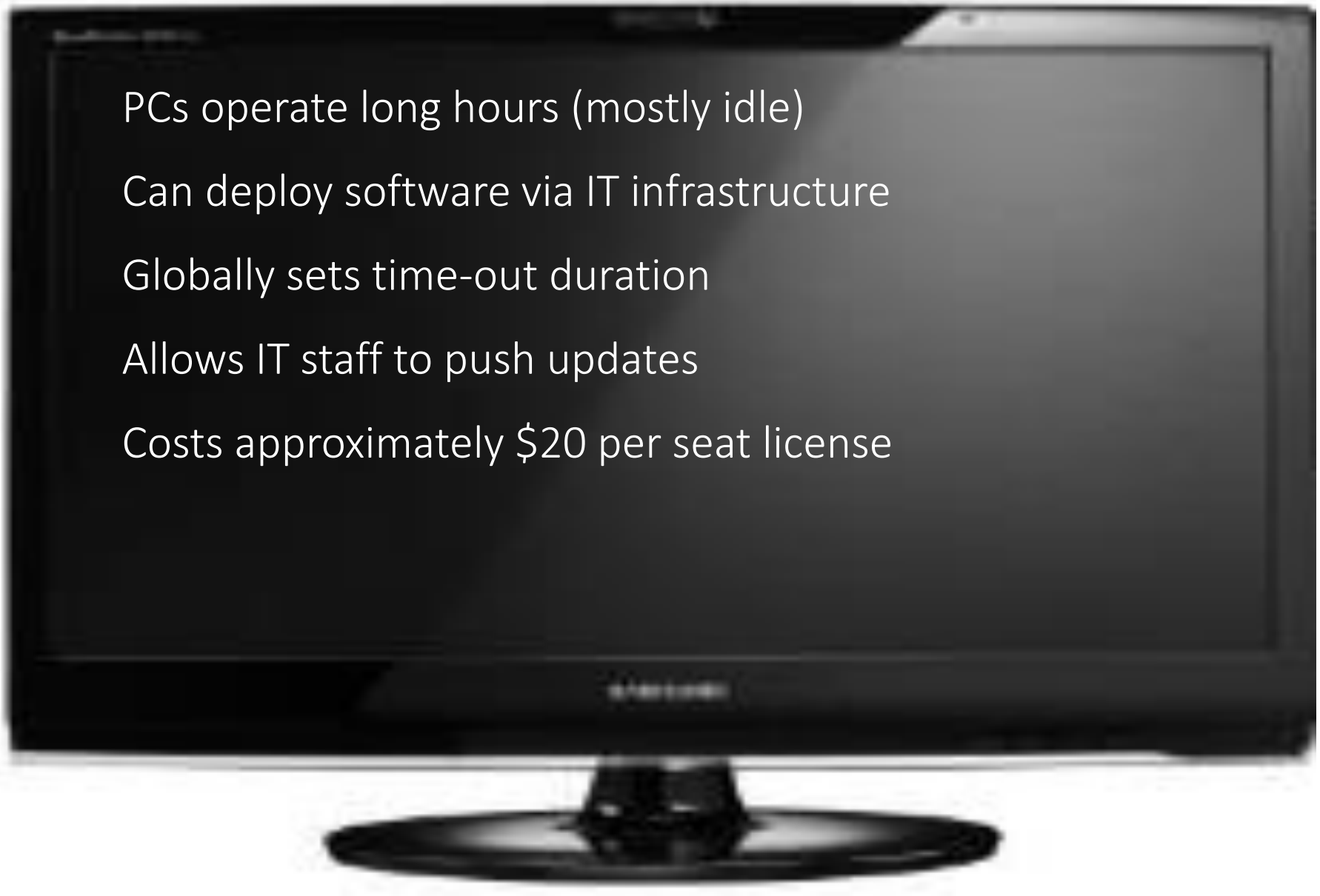


Plug load control - integrated

Use the same occupancy/vacancy sensor as lighting and/or HVAC



PC Power Management Software



- PCs operate long hours (mostly idle)
- Can deploy software via IT infrastructure
- Globally sets time-out duration
- Allows IT staff to push updates
- Costs approximately $20 per seat license

7. Engage Occupants

- Motivating employees/occupants
- Education and training
- Early involvement
- Feedback
- Engagement
- Gamification approaches

Monitoring comfort / IEQ

- Occupant surveys
  - CBE has one that you can purchase www.cbe.berkeley.edu/research/survey.htm
  - Do your own (surveymonkey, e.g.) see ASHRAE's Performance Measurement Protocols for Commercial Buildings

- Real-time feedback
  - Thermovote (U.C. Merced prototype)
  - Genie
  - Comfy

CBE's Survey Tool

Thermal Comfort

Which of the following do you personally adjust or control in your workspace? (check all that apply)

- [ ] Window blinds or shades
- [ ] Operable window
- [x] Thermostat
- [ ] Portable heater
- [ ] Permanent heater
- [ ] Room air-conditioning unit
- [ ] Portable fan
- [x] Ceiling fan
- [ ] Adjustable air vent in wall or ceiling
- [ ] Adjustable floor air vent (diffuser)
- [ ] Door to interior space
- [ ] Door to exterior space
- [ ] None of the above
- [ ] Other:

How satisfied are you with the temperature in your workspace?

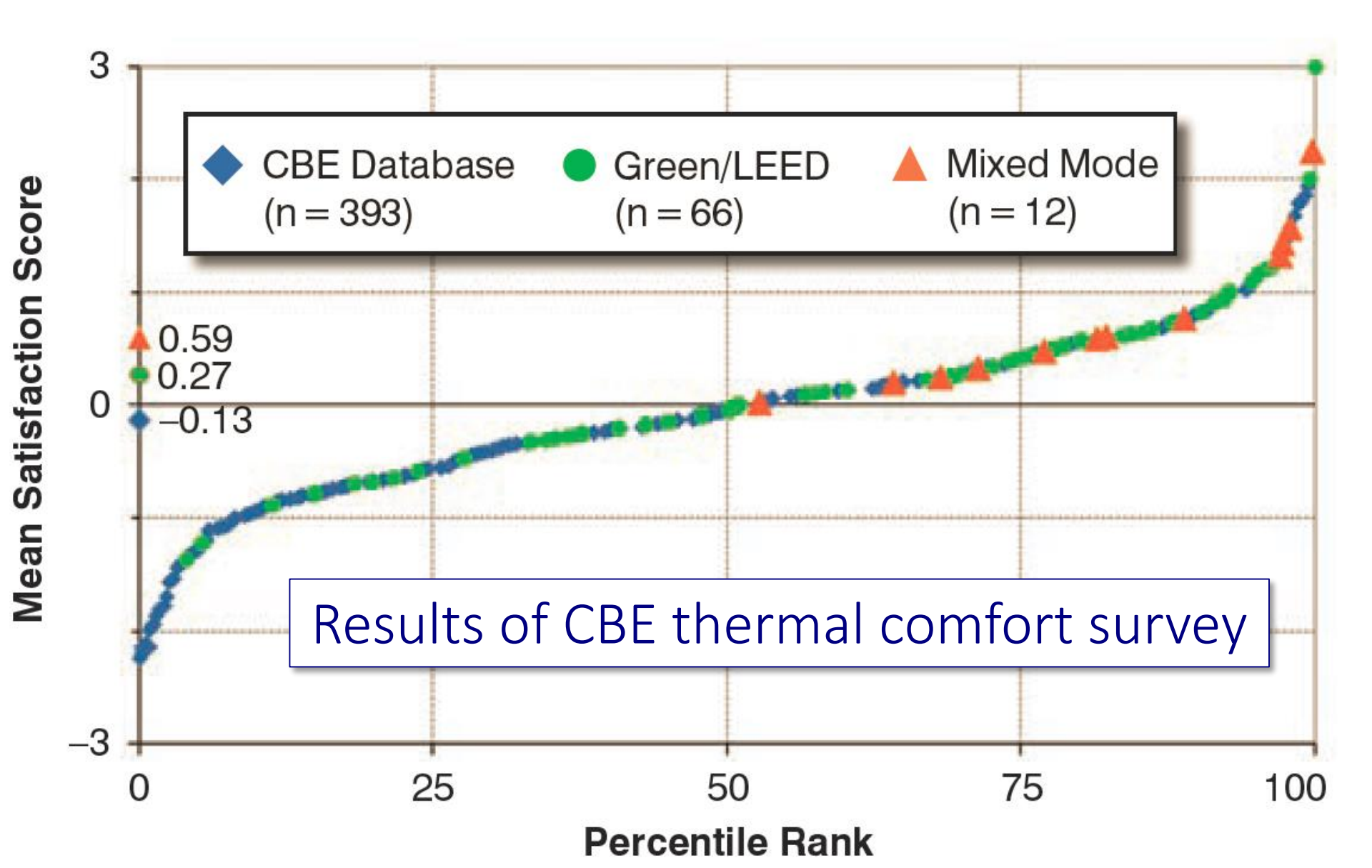
Very Satisfied  Very Dissatisfied

Overall, does your thermal comfort in your workspace enhance or interfere with your ability to get your job done?

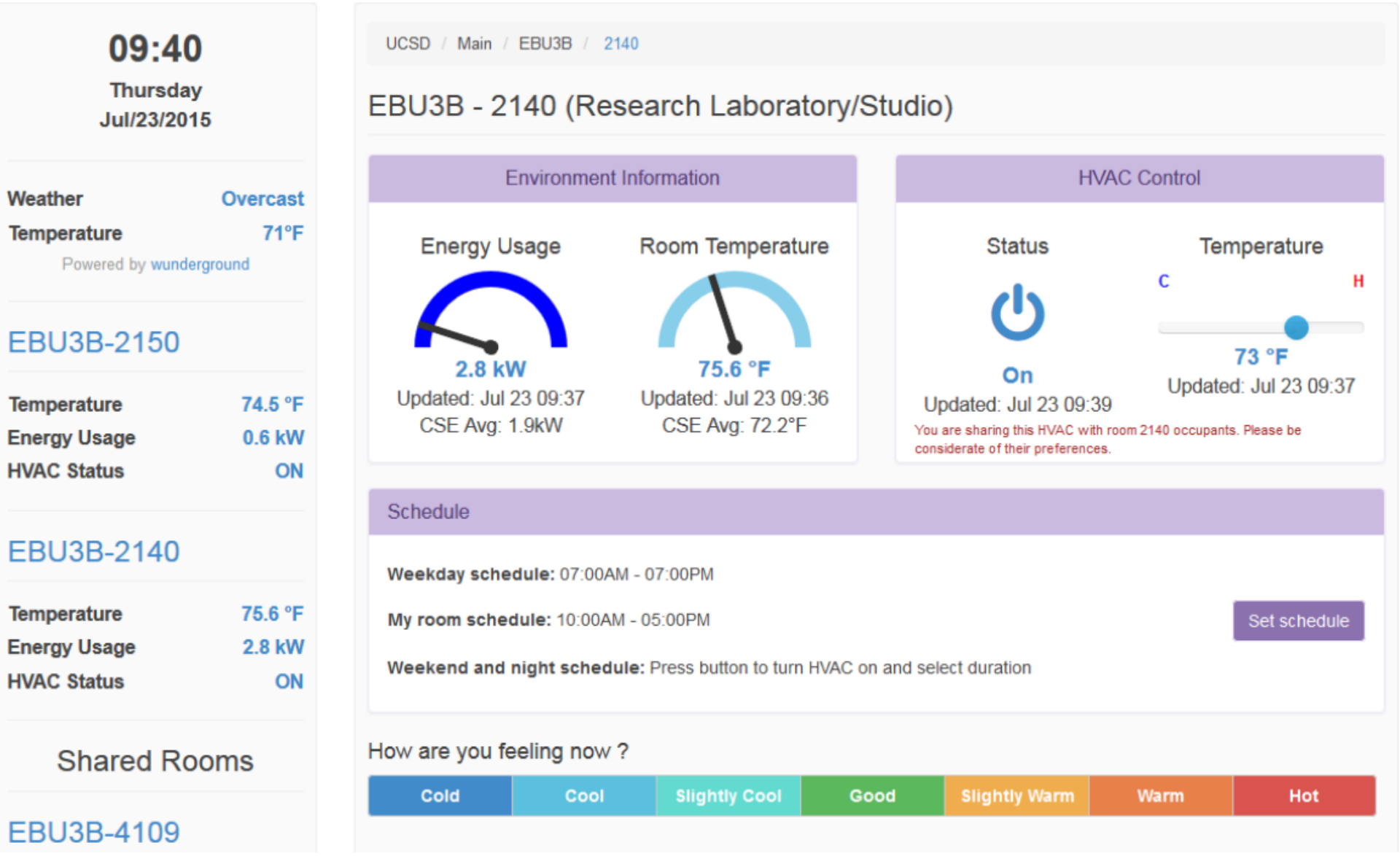
Enhances  Interferes

Continue

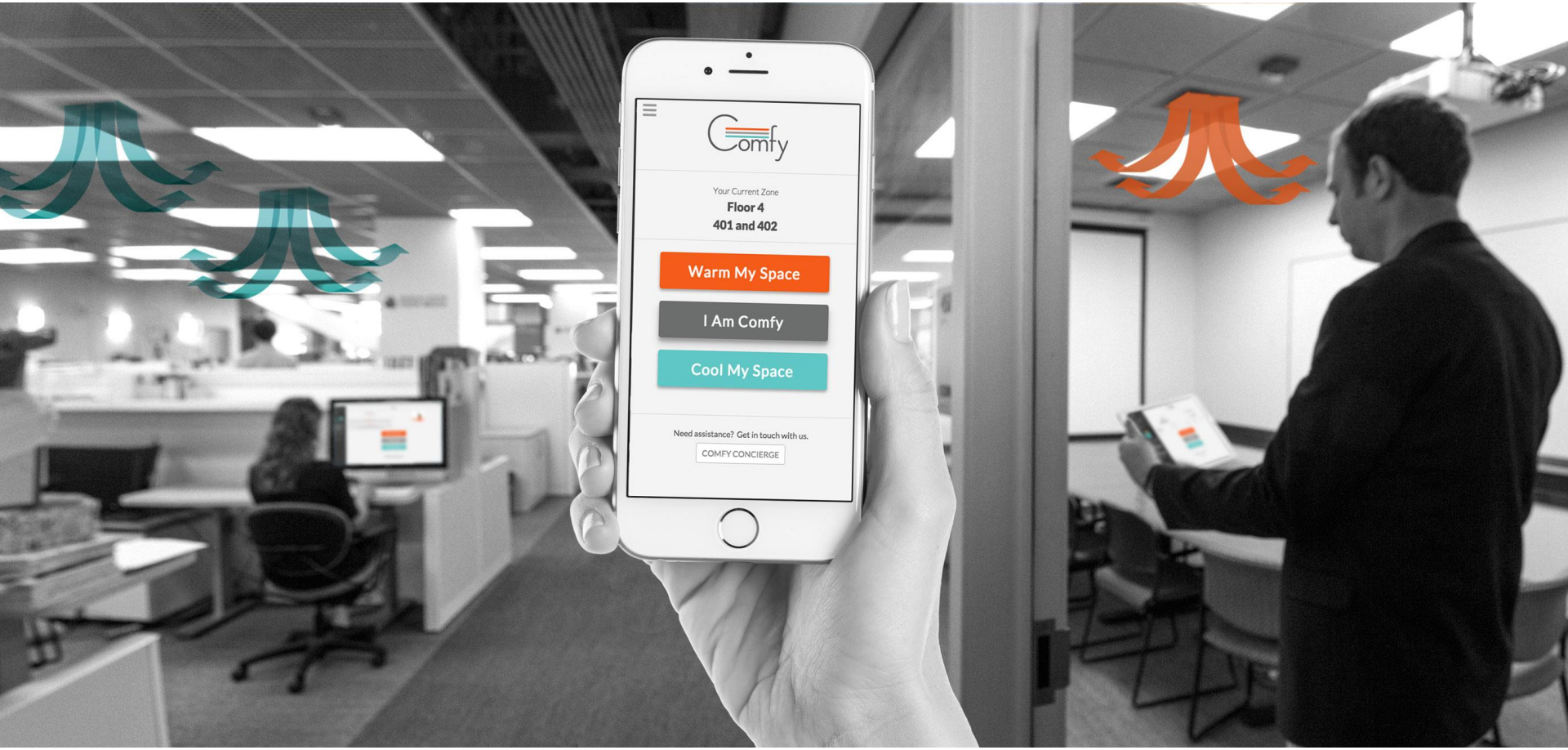
Survey Progress...



Measuring Commercial Building Performance, Protocols for Energy, Water, And Indoor Environmental Quality , Bruce D. Hunn, Ph.D., Fellow ASHRAE; Jeff S. Haberl, Ph.D., Fellow ASHRAE; Hywel Davies, Ph.D., Member ASHRAE; and Brendan Owens, Member ASHRAE, ASHRAE Journal, July 2012

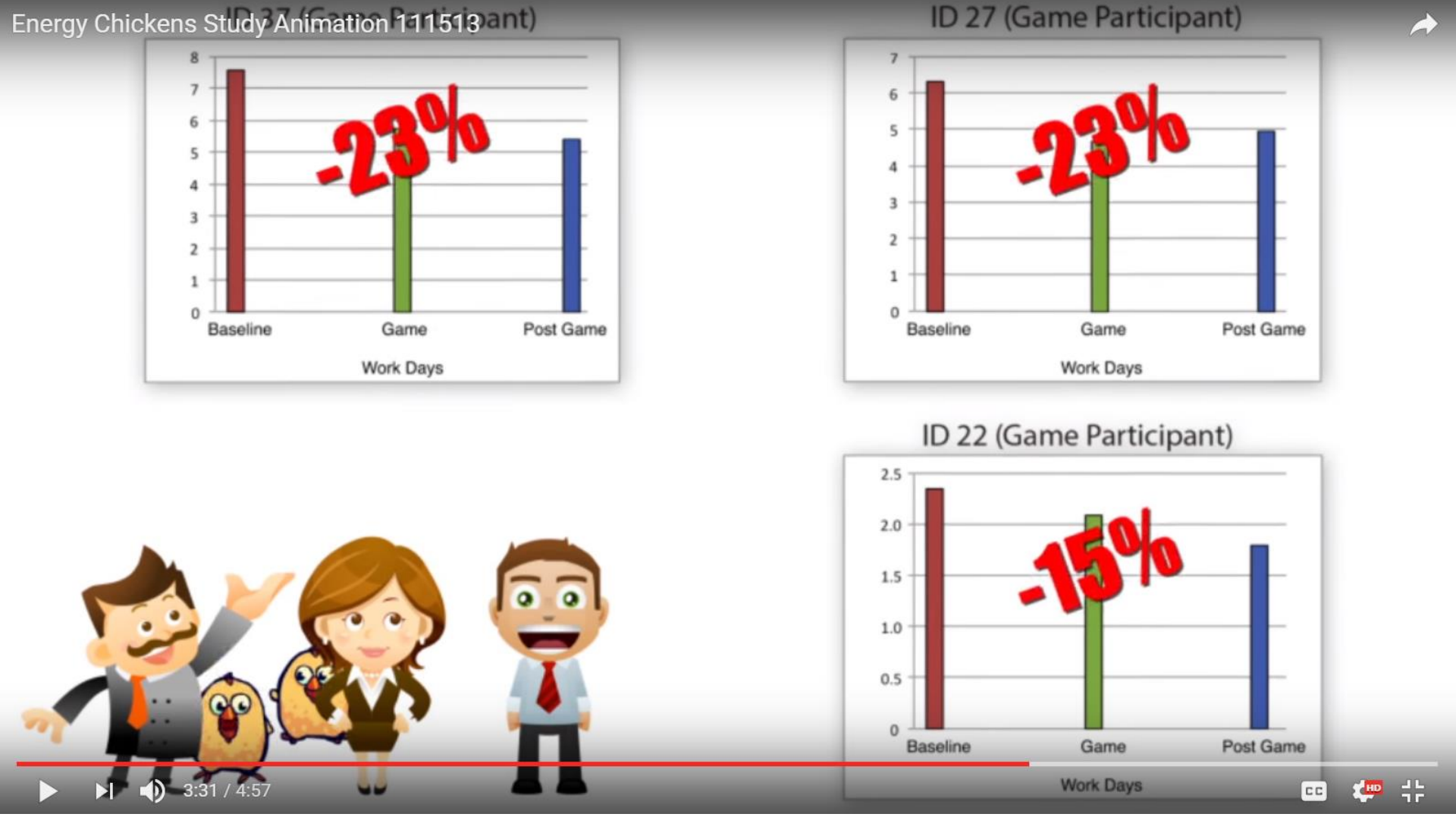


Source: Genie: A Longitudinal Study Comparing Physical andSoftware Thermostats in Office Buildings Bharathan Balaji† , Jason Koh†, Nadir Weibel† , Yuvraj Agarwal‡ †University of California, San Diego ‡Carnegie Mellon University †San Diego, USA ‡Pittsburgh, USA



Simpler interface

- Provides users feedback and direct control
- Widens VAV dead-bands (occupied and un-occ)
- Machine learning for occupancy periods

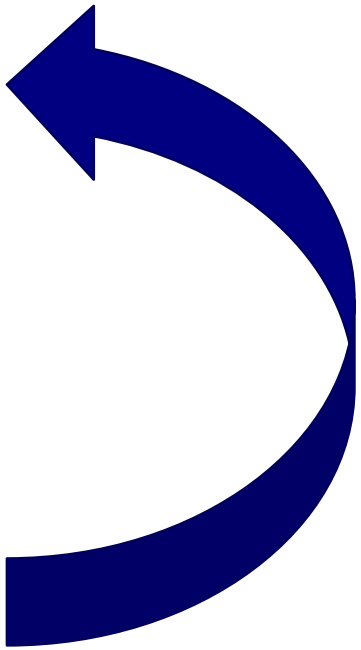


"Gamification" Approaches or "did he say Energy Chickens?"

www.youtube.com/watch?v=6B_ID9qhAvg

Recommended Steps

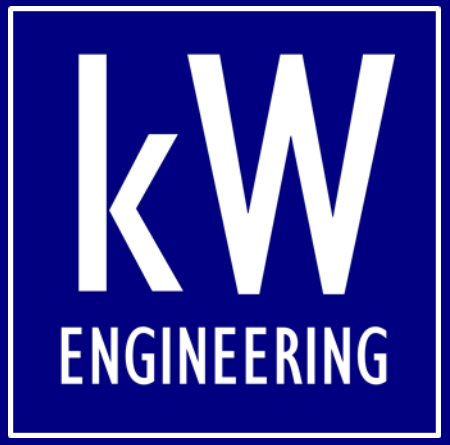
1. Establish role for monitoring performance
2. Budget for integrated design;
   Include Operations Staff in Design Process
3. Utilize simplicity in controls
4. Commission effectively
5. Train site staff
6. Monitor and report performance
   (energy, comfort, IEQ)
7. Engage occupants
8. Make corrections as you go



References

- Control for the People: How Machine Learning Enables Efficient HVAC Use Across Diverse Thermal Preferences, Lindsay Baker and Tyler Hoyt, Building Robotics Inc., ACEEE Summer Study Proceedings 2016.
- Control Sequences & Controller Programming, Mark Hydeman, P.E., FASHRAE; Steven T. Taylor, P.E., FASHRAE; Brent Eubanks, P.E., Associate Member ASHRAE.
- Genie: A Longitudinal Study Comparing Physical andSoftware Thermostats in Office Buildings Bharathan Balaji† , Jason Koh†, Nadir Weibel† , Yuvraj Agarwal‡ †University of California, San Diego ‡Carnegie Mellon University †San Diego, USA ‡Pittsburgh, USA, http://iotexpedition.org/documents/Balaji_Ubicomp2016_Genie.pdf
- Energy Performance Metering to Achieve Zero Net Energy, John Elliott, Chief Sustainability Officer, Sustainable Berkeley Lab, Nov. 2015.
- Zero Net Energy Building Controls Characteristics, Energy Impacts, and Lessons, Industry Webinar, December 8, 2015, Cathy Higgins, Alexi Miller, Mark Lyles, New Buildings Institute.
- Zero Net Energy Case Study Buildings Vol. 1 and 2, Edward Dean, FAIA, Bernheim + Dean, Inc., Foreword by Peter Turnbull, Pacific Gas and Electric Company, Sept. 2014

- Thanks Lyn Gomes and James Donson for input on Commissioning



Thanks

Jim Kelsey
kW Engineering

kelsey@kw-engineering.com